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AN EXAMPLE OF TORSIONAL VISCOUS RETROGRESSION

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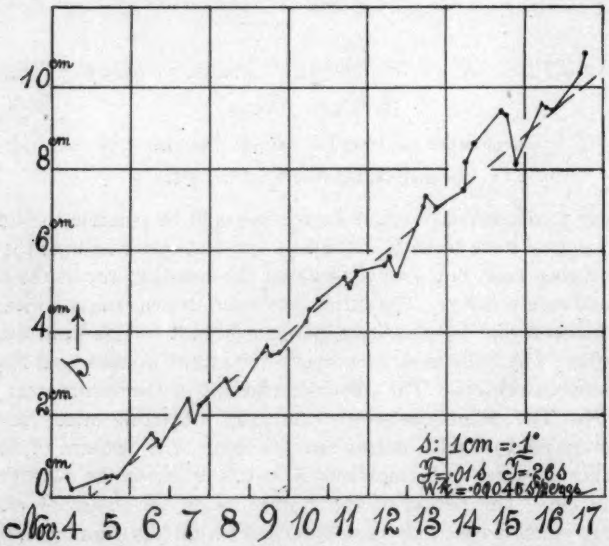
In order to determine to what degree it would be possible to eliminate radiant forces, I have recently installed a gravitational needle of the usual form, in a glass case, but with the balls at the end as heavy as the torsion wire would safely carry. The latter was hand-drawn (music) wire 0.022 cm. in diameter and 154 cm. long, hanging from a torsion head attached to the pier. The balls were each over 1500 grams in mass and 29.3 cm. apart, between centers. The torsion coefficient of the system was found to be 154. The deflections of an externally attracting mass (also 1500 grams) were read off with mirror and telescope at a distance of 290 cm. This makes the force to be measured $F = 0.009s$, if s is the deflection observed in cm. The period of the system would be about 14 minutes. As the two equal masses may be approached within less than 6 cm. of each other (between centers), a gravitational force of about 4.2×10^{-3} dynes is to be registered and this would be equivalent to a deflection of $s = 0.47$ cm. Hence, by commutation, a total deflection of about 1 cm. may be expected, which could be much increased by increasing the masses ($M =$ 1500 g.) on the outside and inside of the case. On the quadratic interferometer with achromatic fringes, the deflection s instanced, would be equivalent to a normal displacement of mirror $\Delta N = 0.023$ cm., readable to 10^{-4} cm. directly, or to 4×10^{-5} per fringe. So far as mere observation is concerned, the reading could be adequately made within 0.1%. I was in hopes, therefore, that the incipient motion of the needle, since air resistance, etc., is here negligible, could be studied as a case of uniformly varied motion.

Observations.—As these were made in a room, at first heated mildly and eventually more vigorously (see curve) they are useless for gravitational work. They are interesting, however, in their bearing on Maxwell's theory of viscosity, as they give evidence of a concealed torsional strain,

gradually but continuously vanishing; or of a spontaneous tendency of the wire to regain the original molecular condition, free from strain. An example of the observation taken in November is given in the figure, and it shows the deflection of the needle (left without direct interference) on successive days.

As to the kinks in the curve which increase enormously (with the advent of cold weather, the need of more heat increases), they may be due to thermal expansion in the supports of the telescope, or to radiant forces.



But as they are always accompanied by a corresponding vibration of the needle, the latter cause must be in preponderance, so that radiant forces are not, even in case of these large masses, to be disregarded.

Apart from the irregularities, the curve, as a whole, rises uniformly, because of the viscous detorsion specified, at a rate of about 0.08° of detorsion per day, and it has kept this up uniformly for months. One may notice that in view of the large weight (over 3 kg.) suspended, the wire is kept at relatively low viscosity, i. e., full of unstable molecular configurations. Utilizing these, the torsional set obtains facility of exit. How the wire acquired this torsional strain is hard to see, unless it was reeled helically. This was probably the case, as the free wire, placed on a plane, shows a helical form, with a pitch of about 2 feet. That the strong tensile strain, which is also vanishing, should, in the suspended wire, make its exit torsionally is improbable, for there would be no reason for the sign of the twist; but the tensile strain probably developed the torsional strain in the lapse of time on the reel.

To eliminate the viscous torsional discrepancy, it would suffice to use the method developed by Dr. Strouhal and myself, of boiling the wire for 20 or 30 hours in water. Such a wire is then practically free from instabilities at atmospheric temperatures.

Finally, since the torque is $0.26s$, the deviation angle $0.0017s$ and the daily detorsion $0.8 = s$, it is interesting to notice that energy is being dissipated at the rate of 0.00014 ergs per day, by the decay of torsion (very small as it is) above. Much more, no doubt, is released in the decay of the intense traction. If the body were not exceedingly opaque, the strained metal would probably be phosphorescent.

THE CHEMICAL ISOLATION OF VITAMINES

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Communicated by W. A. Noyes, November 17, 1919

Vitamines are substances of unknown chemical composition occurring in certain foodstuffs, vegetable and animal tissues. They are essential for the maintenance of health and for normal growth of animals and men. The lower organisms also, such as plants and bacteria, seem to require a certain amount of these vitamines for reproduction and growth. The existence of at least three vitamines is known at the present time, namely, the antiscorbutic vitamine, the deficiency of which in the diet causes scurvy; the so-called fat-soluble vitamine, occurring in butter fat and certain other fats; and the antineuritic vitamine, a sufficient amount of which must be consumed by animals and men in order to prevent the disease called beri-beri. All of these three vitamines are essential for normal growth in man.

During the last few years a study of the relation of vitamines to growth and the maintenance of health has been a fertile field for biologists. These researches have resulted in conclusions of great scientific and practical value. There can be no doubt, however, that many mistaken ideas have arisen in this brief period, due mainly to a lack of knowledge of the chemical character of vitamines. Thus, a few investigators have attempted to ascribe definite chemical and physical properties to substances which at best were possessed only in their crudest and impure form. These inaccuracies can be attributed only to a lack of fundamental, chemical knowledge on the part of these investigators. Every chemist thinks in terms of solubility, dissociation, and other physical chemical properties, but always only in case of a pure substance or mixtures of known composition and not in the case of crude mixtures and extracts of unknown com-

position such as the present-day vitamine preparations. For these reasons work on the chemical composition of vitamines is urgently needed as the previous attempts along these lines have been more or less unsuccessful. This paper deals principally with the antineuritic vitamine.

As it has been found that brewer's yeast is very rich in antineuritic vitamine, this material was selected for this investigation. At first autolyzed yeast was used, but on account of its complex composition it was later on substituted by dried yeast. The general conclusions derived from this work are as follows:

Autolyzed yeast filtrate, on account of its complexity, represents an unsatisfactory material for the chemical isolation of the antineuritic vitamine. Mastic emulsion, Lloyd's reagent (fullers' earth), ferric phosphate, etc., are unsatisfactory adsorbing reagents in that they lack specificity. These reagents remove, also, inactive basic materials which cannot be separated by our present methods from the active material. Olive oil and oleic acid will remove the antineuritic substance from autolyzed yeast filtrate, thus showing that it is fat-soluble as well as water-soluble in the form of a crude extract. Stachhydrine, trigonelline and allied betaines show no antineuritic activity. Histidine and its esters are likewise inactive.

The active material is readily extracted from dried yeast by means of acid methyl alcohol. The extract can be purified by use of the Funk silver method and the mercuric sulphate procedure, yielding an apparently crystalline active substance. This substance becomes inactive upon drying and it is believed that impurities still remain which can be removed with additional modifications of the method described in this paper (see, *J. Biol. Chem.*). The present method eliminates purines, histidine, proteins and albumoses, leaving a liquid that can be crystallized and probably contains histamine or histamine-like substances. The physiological action of the active fractions resembles that of extracts from the mucosa of the small intestine, when the intestinal and yeast extract are purified in the same manner.

A NEW METHOD OF DETERMINING THE SOLAR CONSTANT OF RADIATION

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Read before the Academy, November 10, 1919

The Smithsonian Astrophysical Observatory has been engaged for more than ten years in measuring the intensity of the solar radiation at the earth's surface under such conditions that the intensity as it would be outside the atmosphere may be computed from the observations. The

method employed hitherto has been the method of Langley which consists of two essential parts. First, measurements with the pyrheliometer of the intensity of solar radiation at the earth's surface. Second, measurement by the spectro-bolometer, covering several hours' time, designed to determine the transparency of the atmosphere for all colors in the spectrum. This latter part of the work demands a uniform transparency of the atmosphere during the several hours required for determining it. This condition is never perfectly met by terrestrial conditions. The changes in the atmospheric transparency not infrequently introduce an error of 1 and sometimes 2 or 3% in the results of the observations at the best stations, although on many days of observation the condition of uniform transparency is so well fulfilled that the results appear to be accurate to a fraction of 1%. If we were interested only in the absolute value of the solar constant of radiation it would be possible to nearly eliminate this source of error by a sufficient number of observations. But it has been shown that it is highly probable, I may say indeed certain, that the solar radiation is variable from day to day through a range of several per cent. The source of error which has been described is a principal difficulty against determining the real variations of the sun on which variations of the weather seem to depend.

My colleagues and myself have long sought to discover a method of determining the solar radiation outside the atmosphere which would be independent of these variations of transparency. We sought to do this through the observations of the brightness of the sky. It is well known that the sky owes its brightness to the scattering of the solar rays by the molecules and small particles which compose our atmosphere. The more hazy the sky, the greater its brightness and the less the atmospheric transparency. Accordingly, it seemed to us hopeful to determine the atmospheric transmission coefficients in terms of the brightness of the sky. We employed in the investigation a new instrument which we call the pyranometer designed to measure the brightness of the whole sky or of any fraction of it, either on a horizontal surface or on a surface at right angles to the average direction of such a portion of the sky as might be under observation. While at Calama, Chile, in June, 1919, I took up the matter with Mr. Moore, the director of the Smithsonian observing station there. He placed at my disposal determinations of the transparency of the atmosphere for nearly forty wave-lengths, pyranometer values representing the intensity of the radiation of the sky in a zone 15° wide surrounding but not including the sun, and measurements of the intensity of the solar radiation by the pyrheliometer and by the spectro-bolometer. All of these values were tabulated with the solar constant values for 60 days of observation. The pyranometer values and values of a function which we call ρ/ρ_{sc} were taken on each day at the periods

when the air masses were 2 and 3, respectively, that is to say, when the zenith distance of the sun is about 60° and about 70°.

The function ρ/ρ_{sc} is determined in this way: A spectrum-energy curve taken through the solar spectrum shows deep depressions in the infra-red spectrum, one of which was termed by Langley $\rho\sigma\tau$. Measurement is made of the ordinate of the smooth curve drawn across the top of the depression, and another measurement of the ordinate at the minimum of the depression. The ratio of these two ordinates forms the function ρ/ρ_{sc}. It is a measure, as Mr. Fowle has shown, of the quantity of humidity prevailing in the atmosphere between the observer and the sun. Mr. Fowle indeed has worked out a method of determining the actual amount of precipitable water in the vertical column of the atmosphere by a mere measurement of the value ρ/ρ_{sc}.

Since the haziness of the atmosphere is closely related to its humidity, but since the haziness also depends upon the amount of dust taken up from the soil by the wind, or such as is occasionally distributed in the upper air by volcanic eruptions, we hoped to get a complete indicator of the haziness prevailing by a combination of the value ρ/ρ_{sc} with the value of the sky brightness, determined by the pyranometer, in the immediate neighborhood of the sun. We formed the function "sky brightness divided by ρ/ρ_{sc}," which we will call "F." After a number of unsuccessful investigations I was led by a suggestion of Mr. Moore's to find that the values of the atmospheric transmission coefficients for the individual wave-lengths in the spectrum could be represented in terms of the function "F" by smooth curves in which atmospheric transmission coefficients were plotted as ordinates and the function "F" as abscissae. All of the data for the sixty days available were plotted in this manner for each of the 40 wave-lengths above mentioned. The atmospheric transmission coefficient varies by only 2 or 3, or at most 5% in any part of the spectrum, while the function "F" varies through a range of from 100 to 1000 or more on a certain scale. Hence, it is clear that great errors in determining the function "F" would produce very small errors in determining the atmospheric transmission.

The measurements required to determine the function "F" may be all completed within ten minutes. Entering the plots above mentioned with the values of the function "F" as thus determined, we take out from the plots the atmospheric transmission coefficients for all wave-lengths in the spectrum. With these data we may immediately determine the solar constant of radiation by the usual method of computation.

The new method has been in application at Calama, Chile, since about July 1. Measurements by the older method, on which it is primarily based, have been taken on about one-third of the days, and measurements by the new method on practically all days since July 1. It is found that the agreement between the results of the older method and of the new

abridged method is very close. In a comparison recently made, covering 53 days on which observations by both methods were available, it was found that on 32 days the result by the new and the old methods agreed within less than 1%, and on 45 days within less than 2%. It was found, also, that on the days in which the agreement was not good, some change in transparency appeared to be occurring which would reasonably account for the discrepancy on the ground that the value by the old method had been impaired thereby.

The new method is applicable on many more days than the old, and it has the further advantage that several independent observations of the solar constant of radiation may be made by the new method on a single day of observation. We believe that by checking the new method against the old from time to time it will be possible to assure ourselves of the accuracy of it, and we propose to employ it principally, hereafter, in our determinations of the solar constant of radiation.

THE BASAL METABOLISM OF BOYS FROM 1 TO 13 YEARS OF AGE

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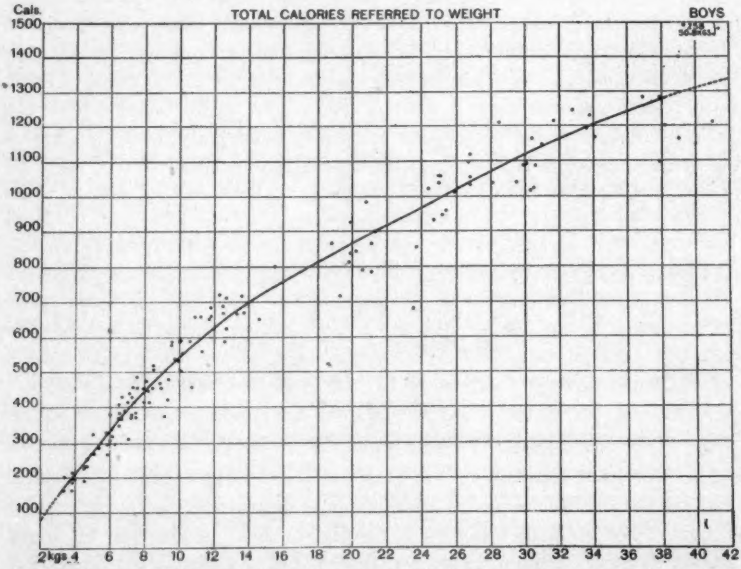
Read before the Academy, November 10, 1919

The Nutrition Laboratory has been occupied for a decade in an effort to chart the field of the basal metabolism of humans of both sexes and of all ages. By basal metabolism is meant the heat production for maintenance during complete muscular repose and without active digestion. From a biometric analysis[1] of the studies already made of men and women, it is clear that weight, stature, age, and sex all have an independent influence upon the basal metabolism.

With growing boys the rapid changes in weight, stature, and age make metabolism measurements of unusual interest. The data that are reported herewith, representing 128 observations on boys ranging in age from a few months to 13 years and above, were all obtained with the coöperation of Dr. Fritz B. Talbot of Boston and the detailed results of the investigation will shortly be published in conjunction with him by the Carnegie Institution of Washington.

The total calories per 24 hours referred to weight are indicated for all the subjects in the chart. A general inspection of this chart shows a distinct trend which follows a reasonably regular course. The scatter of the points about this curve is perhaps surprisingly small, especially when we consider the usual scatter with adults. Indeed, until the collection of

more extensive data shows a different picture, it seems possible to use this curve for predicting the probable basal metabolism of boys within this age-period. Although at first sight it would appear as if the grouping of the points around the curve were closer for the boys weighing less than 10 kg. than for those of greater weight, percentagewise, the deviations are greater at the lower weights. The curve has, therefore, been arbitrarily divided for consideration into two sections showing the values obtained with boys below and above 10 kg., respectively.



BASAL HEAT PRODUCTION OF BOYS PER 24 HOURS REFERRED TO BODY WEIGHT

By comparing the actually measured heat output per 24 hours for these boys with the predicted heat output read from this curve for corresponding weights, we find that with 60 subjects below 10 kg., the prediction average is 368 calories against an average of 364 calories from measured values. With 68 subjects above 10 kg., the average predicted value is 911 calories as compared with 907 calories obtained by actual measurement.

These pictures can be looked upon only as a proof of the legitimacy of the curve as sketched. But when individual cases are considered, we find that with boys under 10 kg. there is an average plus or minus deviation of predicted from actual of 30 calories or somewhat over 8%. With the 68 values above 10 kg. the predictions are considerably closer, since the deviations are plus or minus 54 calories on the average, or an average difference of 6.3%. It thus appears that from this curve alone one may

predict the heat output of boys weighing 10 kg. and above to within an average accuracy of a little over 6%.

From data obtained by the Nutrition Laboratory of the basal metabolism of 136 men, Dr. J. Arthur Harris[1] has derived by biometric analysis a multiple prediction formula which may be used for predicting the 24-hour basal heat production of men, as follows:

$$h = + 66.4730 + 13.7516w + 5.0033s - 6.7550a$$

In this formula h = total heat production per 24 hours, w = weight in kilograms, s = stature in centimeters, and a = age in years.

Although in publishing this formula, it was specially emphasized that its application to the lower ages was not yet justified, owing to the fact that of the 136 subjects studied, but few were below 20 years of age, it has been of unusual interest to attempt a prediction of the heat output of these boys, using the multiple prediction formula for men. By this entirely independent method of prediction, we find that the average metabolism of the group of boys above 10 kg. is predicted to within 6 calories, that is, 907 calories actual as against 901 calories predicted. The average deviation for individual predictions is plus or minus 56 calories or 6.3%, giving a prediction with an accuracy identical with that obtained from the curve. This is of considerable practical importance as evidence that the metabolism of males ranging from boys of 10 kg. up to full grown adults, including the period of old age, may be predicted with this formula with an accuracy of not far from plus or minus 6%. For ordinary purposes the pediatrician will prefer to use the values drawn from the curve. To simplify its use, a table giving the most probable heat production of boys per 24 hours predicted directly from body weight has been prepared.

BASAL HEAT PRODUCTION OF BOYS PER 24 HOURS PREDICTED FROM BODY WEIGHT

WEIGHT	CALORIES	WEIGHT	CALORIES	WEIGHT	CALORIES	WEIGHT	CALORIES
kg.		*kg.*		*kg.*		*kg.*	
		11	590	21	885	31	1140
		12	625	22	910	32	1160
3	150	13	660	23	940	33	1180
4	210	14	695	24	965	34	1200
5	270	15	725	25	990	35	1220
6	330	16	755	26	1020	36	1240
7	390	17	780	27	1045	37	1255
8	445	18	805	28	1070	38	1275
9	495	19	830	29	1090		
10	545	20	860	30	1115		

While with adults it was clearly demonstrated that in predicting the heat output consideration should be given not only to body weight but likewise to age and stature, it is evident from this treatment that the pre-

diction from the curve based on body weight alone is of equal value with that from the formula, taking into consideration not only weight but also stature and age. This is probably in large part explained by the fact that with boys the changes in age, weight, and stature are closely correlated.

[1] Harris and Benedict, *Carnegie Inst., Washington, Pub.*, No. 279, 1919; see also these PROCEEDINGS, **4**, 1918 (370–373).

THE NATURE AND FUNCTION OF THE ANTINEURITIC VITAMINE[1]

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Communicated by W. A. Noyes, November 17, 1919

Introductory.—Prior to and immediately following the year 1897 various theories were advanced by different investigators relative to the etiology of the oriental disease known as beri-beri. The merits and demerits of the various theories extant at that period are discussed in a very comprehensive way by W. L. Braddon in his book, "The Cause and Prevention of Beri-Beri." It will suffice to say that the prevailing theories held at that time explained the etiology of the disease in terms of bacteria, bacterial poisons, or poisons contained within the food.

During the years 1889 to 1897 Eijkman and his colleagues had advanced the study of the disease to the point where they were able to demonstrate that beri-beri could be produced at will on a diet consisting solely of polished rice, but that a cure could be effected and a recurrence of the disease prevented by the use of hand-milled rice. Eijkman[2] also showed that a disease similar to human beri-beri could be produced in fowls by diets composed of polished rice and that the paralytic symptoms disappeared upon the administration of rice polishings or alcoholic extracts of rice polishings. Schaumann,[3] in 1910, introduced a phosphorus-deficiency theory, basing his convictions upon the fact that all curative foodstuffs possessed a high percentage of phosphorus, while in the case of the non-curative foods the reverse seemed to be true. Schaumann believed the organic phosphorus-containing compounds to be essential in the treatment of beri-beri. This theory was propounded at a time when a great deal of importance was being attached to the lipoid content of the dietary. Other writers[4,5] have shown that a parallelism exists between the phosphorus content of cereals and their vitamine activity, but this parallelism is considered to be fortuitous rather than an actual chemical relationship.

Views Concerning Its Chemical Characteristics.—In 1911 Funk[6] announced

that he had been successful in isolating an organic base, $C_{17}H_{18}O_4N(HNO_3)$, from rice polishings which possessed a curative action. On account of the fact that this nitrogenous substance was apparently indispensable to life, Funk gave it the title "vitamine." This was the origin of the vitamine hypothesis.

Since 1911–12 a number of investigators have studied many phases of the vitamine problem with the result that much has been learned concerning the vitamine content of various food materials and the effect of these diets on the growth and development of animals. However, very little advancement has been made in ascertaining with greater certainty the chemical nature of the anti-beri-beri vitamine. Following the publication of Funk's article, Edie[7] and his co-workers announced the isolation of a basic substance from yeast to which was ascribed the formula $N(CH_3)_3C_4H_7O_2(NHO_3)$. They named the substance "Torulin." Suzuki, Shimamura and Odake[8] also publishing the same year obtained a pure chemical substance from rice polishings which possessed a curative action. This substance they identified as nicotinic acid. During the same year Schaumann[9] prepared a phosphorus-free nitrogenous base which had curative properties. He advanced the hypothesis that this base acts as an "activator," stimulating the synthesis of phosphatids which are essential in the regeneration of degenerated nervous tissue.

Funk[10] believed that the curative substance was chemically related to the pyrimidines or purines. To test this hypothesis he fed allantoin, hydantoin, thymus nucleic acid and cytidine, obtaining varying degrees of improvement in polyneuritic birds.

Williams[11] found that the hydroxyl pyridines possessed curative properties which were lost on standing; this, he explains, is probably due to tautomerism and he suggests that the instability of vitamines may be explained on a similar basis. In a later publication[12] this writer concludes that the curative form of α-hydroxyl pyridine is structurally a pseudobetaine. He postulates that nicotinic acid and possibly vitamines are of a similar nature. Harden and Zilva[13] confirmed the chemical facts regarding the α-hydroxyl pyridines and adenine, as put forth by Williams, but failed to obtain relief in avian polyneuritis when these preparations were fed. Voegtlin and White[14] also failed to obtain results as reported by Williams and Seidell.[15]

Views Concerning Its Metabolic Functions.—Funk[16] made the observation that when no food was metabolized beri-beri symptoms did not appear, while an increase in food intake, especially carbohydrate food, hastened the paralytic symptoms. This has been substantiated by other investigators, including the writer, except that we are inclined to believe that overloading the oxidative mechanism with any energy-producing food will usually hasten the onset of symptoms. Funk and Schönborn[17] associate this type of vitamine with carbohydrate metabolism and es-

pecially starch metabolism. On vitamine-free diets these authors obtained hyperglycemia with diminished amounts of hepatic glycogen. Vitamine-free and carbohydrate-free diets, in the opinion of these writers, prevents in some manner, the synthesis of glycogen from protein and fat. Vitamine diminished the hyperglycemia and increased the liver glycogen.

The first work recorded, so far as the writer is aware, concerning the relation of vitamine to pathology, is that of Funk and Douglas[18] and Douglas.[19] Pathological examination of the pituitary, thyroid, suprarenals, ovary, testes, kidney, liver, pancreas and spleen showed that on a vitamine-free diet all glands diminished in size and underwent degenerative changes. The thymus gland was caused to disappear and then return by the administration of vitamine.

Drummond[20] has published data indicating that creatinuria follows the feeding of diets deficient in the anti-neuritic vitamine. In this work rats were used as the experimental animals.

Studies made in this laboratory have led us to believe that the vitamine functions indirectly as a metabolic stimulant. We have observed[21] that the body temperature falls during the development of avian polyneuritis and increases after vitamine administration. Measurement of the catalase content of the tissues in polyneuritic birds revealed a drop in catalase activity to a point 56% below normal, indicating that oxidative processes are depressed when the organism is not receiving the normal amount of vitamine. It is not improbable that the depression of body oxidations is accompanied by the formation of toxic metabolic products which affect the nervous system, bringing about the typical paralysis and other symptoms.

The mechanism of the stimulation and cure, when vitamine is fed, is not clear. Certainly the process is not a simple one. It would appear that there is some relationship between vitamine intake and endocrine activity. Mr. S. D. Wilkins, working in this laboratory, has recently caponized Single Comb White Leghorn cockerels whose sole diet, for from three to five weeks, was polished rice. The testicles were found to be atrophied to a surprising degree, often being not more than 20% of normal in size and weight. He has been able to show the effect of diet in this connection by removing but one testicle in each rice-fed bird and immediately afterward adding green alfalfa to the rice diet. The birds on the rice-alfalfa diet grow and increase in weight. Upon caponizing these birds the remaining testicle has increased in size and weight, approaching that of the normal birds. Jackson and Stewart[22] point out that underfeeding brings about atrophy of practically all vital organs, including the testes, accompanied by a loss in body weight. Refeeding does not produce normal growth and none of the animals attain the size and weight of the control animals. This, these writers point out, differs from the results

of Osborne and Mendel[23] who concluded that the capacity to grow is not lost on inadequate diets.

The remarkable growth of the animals refed by Osborne and Mendel may have been due to the fact that the diets were adequate in quantity and quality with respect to vitamines and other ingredients with the exception of protein. The organs and ductless glands probably received sufficient nourishment and stimulation to prevent appreciable atrophy. In the case of the underfed rats of Jackson and Stewart the diet was quantitatively inadequate with the result that pathological changes (atrophy) went too far for the normal processes to be restored.

We have been able to obtain decided atrophy of the testes in cockerels without a loss in body weight, which eliminates any possibility of explaining the condition on a starvation or inanition basis. McCarrison[24] has obtained similar results with pigeons, finding atrophy of many of the ductless glands and vital organs. While inanition plays a part, this author believes the unusual pathological condition to be due to the absence of vitamines, which he calls "nucleopasts," due to the fact that he believes them to be essential for nuclear metabolism.

From the standpoint of the feeder and the live-stock producer, as well as from the sociological standpoint, this work suggests two important things which merit emphasis: first, the question of diet in relation to sexual vitality, sterility, etc., and second, the importance of green, fresh feed for all growing animals, especially poultry. Proprietary poultry feeds are often largely carbohydrate in composition, poor in protein and low in vitamine and mineral matter. Many diseases are undoubtedly brought about by poor diets, lowering the resistance of the animal to invading organisms. The rôle that the vitamine plays in this connection in unknown.

We have cured limberneck in fowls by administering a vitamine extract prepared from wheat germ. In each case recovery was preceded by copious bowel evacuations. The action in this case is probably not a typical vitamine action, but there is little doubt but that the vitamine plays its part in the rapid recovery of the birds. Neither do we wish to leave the impression that limberneck is a deficiency disease; in fact, we have been unable to produce it by any method of feeding or treatment. Uhlmann[25] states that water-soluble vitamine acts in a manner very similar to pilocarpine, stimulating gland secretion. It is very possible that the laxative action of many fruits, vegetables, whole grains and brans, is due, in a measure, to increased gland secretion brought about by vitamine stimulation.

With Uhlmann's work in mind and also the work of Kendall,[26] who isolated thyroxin, the hormone of the thyroid gland, we[27] have fed polyneuritic pigeons the stimulants thyroxin, desiccated thyroid, pilocarpine hydrochloride and tethelin. The thyroxin and thyroid were fed because

of Kendall's findings that energy production was dependent upon thyroid activity. Pilocarpine hydrochloride was used because of Uhlmann's work mentioned above. Tethelin, the growth-controlling principle of the anterior lobe of the pituitary body,[28] was fed for similar reasons. All of these substances produced definite relief and cessation of polyneuritic symptoms. The response was slower in all cases than when vitamines are fed.

The hormones from the ductless glands undoubtedly influence to a marked degree the activity, health, growth and well-being of animals. May it not be possible that the hormone supply is dependent upon the vitamine content of the food? As a result of our observations, we wish to suggest tentatively that the activity of the organs of internal secretion are dependent upon the stimulatory action of the vitamine. Whether this is in the nature of a nerve stimulant, nuclear nutrient or the chemical nucleus of a hormone is, of course, a matter of speculation.

[1] Published with the approval of the Director, as Paper No. 185, Journal Series, Minnesota Agricultural Experiment Station.

[2] Eijkman, C., *Virchow's Arch. path. Anat.*, **148**, 1897 (523–532).

[3] Schaumann, H., *Arch. Schiffs- und Tropen-Hygiene*, **14**, 1910 (325–721).

[4] Voegtlin, C., and Myers, C. N., *Pub. Health Rep.*, **33**, 1918 (911–917).

[5] Green, H., *S. African J. Sci.*, **14**, 1918 (519–520).

[6] Funk, C., *J. Physiol.*, **43**, 1911 (395–400).

[7] Edie, E. S., Evans, W. H., Moore, B., Simpson, G., *Biochem. J.*, **6**, 1912 (234–242).

[8] Suzuki, U., Shimamura, I., and Odake, S., *Biochem. Zs.*, **43**, 1912 (89–153).

[9] Schaumann, H., *Arch. Schiffs- und Tropen-Hygiene*, **16**, 1912 (349–361, 825–837).

[10] Funk, C., *J. Physiol.*, **45**, 1912 (489–492).

[11] Williams, R. R., *J. Biol. Chem.*, **25**, 1916 (437–445).

[12] Williams, R. R., *Ibid.*, **29**, 1917 (495–520).

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RECONSTRUCTION OF THE SKELETON OF THE SAUROPOD DINOSAUR CAMARASAURUS COPE (MOROSAURUS MARSH)

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The principles of modern research in vertebrate palæontology are illustrated in the fifteen years' work resulting in the restoration of the massive sauropod dinosaur known as *Camarasaurus*, the "chambered saurian."

The animal was found near Canyon City, Colorado, in March, 1877. The first bones were described by Cope, August 23, 1877. The first attempted restoration was by Ryder, December 21, 1877. The bones analyzed by this research were found probably to belong to six individuals of *Camarasaurus* mingled with the remains of some carnivorous dinosaurs, all from the summit of the Morrison formation, now regarded as of Jurassic-Cretaceous age. In these two quarries Cope named nine new genera and fourteen new species of dinosaurs, none of which have found their way into palæontologic literature, excepting *Camarasaurus*. Out of these twenty-three names we unravel three genera, namely:

One species of *Camarasaurus*, identical with *Morosaurus* Marsh.

One species of *Amphicœlias*, close to *Diplodocus* Marsh.

One species of *Epanterias*, close to *Allosaurus* Marsh.

The working out of the *Camarasaurus* skeleton results in both the articulated restoration and the restoration of the musculature. The following are the principal characters: The neck is very flexible; anterior vertebrae of the back also freely movable; the division between the latter and the relatively rigid posterior dorsals is sharp. Double spines of the cervicals and flexible anterior dorsals show through the skin of the restoration. Spines of the relatively inflexible dorsals, sacrals and caudals are comparatively low and broad. The breadth of neck, thorax, and pelvis, as shown by the bones, is relatively greater than in other sauropodous dinosaurs. The tail had no terminal whip-lash. The scapula is very massive and expanded at the summit. The cross-section of the thorax is relatively much broader than in other Sauropoda. The general conclusion is that *Camarasaurus* was a very broad and massive, slow-moving sauropod, in fact, the most massive reptile in proportions that has ever been found.

This study is part of the senior author's research for the *Monograph on the Sauropoda* in preparation for the U. S. Geological Survey.

RESTORATION OF CAMARASAURUS AND LIFE MODEL

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The muscular restoration of *Camarasaurus* was preceded by careful studies of the consecutive poses of the skeleton of *Apatosaurus* (*Brontosaurus*) in three phases of the stride. These poses were worked out in a minature model of the complete skeleton, with flexible joints. The conclusion reached is that *Apatosaurus* was a walking and not a crawling quadruped. As compared with living crocodiles the body was well raised off the ground in the stride. This is contrary to the ideas of Tornier, Hay and others, who advocated a crawling stride. The limbs, however, had not the fore-and-aft pendulum action of the perfected mammalian quadrupeds; the stride had a wide, lateral swing.

Subsequently a complete restoration of the musculature of *Camarasaurus* was made in comparison with living reptiles. The prominence of the muscle lines is justified by studies of recent alligators, in which certain muscle groups stand out as low humps in action. The pose selected was based directly on a photograph of a rapidly walking alligator, the right fore foot having just descended without the natural continuation of the stride by the hind feet.

The special points noted in the position of the bones of the skeleton are the following: Scapula gently, not sharply, inclined backward; inferior position of the scapulocoracoid, which was brought relatively near its fellow on the opposite side; spreading upper border of the scapula implying an essentially reptilian arrangement of the trapezius and other muscles; moderate bending and eversion of the elbow in the stride, the motions of the arm bones being essentially similar to those of the crocodiles but with the elbow joint less strongly flexed; digitigrade position of the bones of the fore limbs and manus. The fore limb as a whole contrasted widely with that of the mammal. Pelvic musculature and arch fundamentally similar to those of the Crocodilians. At no time did the head of the femur fill the acetabulum. The backbone is elevated above the shoulder blade in the walking pose. The tail of *Camarasaurus* is relatively smaller in transverse section than that of Crocodilians, with correspondingly weak muscles.

Camarasaurus might well have been an efficient wader. It was positively devoid of special adaptations for swimming; the pectoral and pelvic arches, and the limbs and backbone were adapted to support the great weight of the body presumably on land, as well as in wading; the tail was relatively small and feeble. There was a high ratio of limb power to weight.

The most decisive points in favor of the theory that *Camarasaurus*

was able to walk with the body well raised off the ground are the following: (1) Inability to flex strongly the elbows, evidenced by the characters of the distal facet of the humerus. (2) Ability to turn the femur well forward, like that of carnivorous dinosaurs. (3) Detailed resemblances of the femur to that of *Stegosaurus*, assuredly a straight-limbed reptile. (4) Total dissimilarity between the humerus and femur of sauropods and those of primitive Permian reptiles.

PLATO'S ATLANTIS IN PALAEOGEOGRAPHY

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The classic story of Atlantis has been supposed by some writers to be a genuine tradition, and to be supported by scientific evidence, which they believe indicates a land bridge across the Atlantic in former geologic times. The island of Atlantis as described by Plato they suppose to be a remnant of this bridge. Examination of the story in detail shows that it is a fable, and that the scientific evidence does not lend any support whatsoever to it nor vice versa.

The existence of a transatlantic bridge in Tertiary or pre-Tertiary times is a legitimate scientific question, which should not be confused with the fabulous story of Plato. The present writer does not, however, believe that such bridges are necessary. Their existence during the Tertiary period cannot apparently be reconciled with the known history of vertebrate evolution on the two sides of the Atlantic. The supposed arguments in their favor from the distribution of certain lower animals and plants can all be otherwise explained; and the arguments that favor a general permanency of the ocean basins afford grave objections to any such bridges, especially of such recent date, geologically.

Transatlantic bridges in pre-Tertiary times are theoretically more plausible simply because there is less positive evidence against them. The evidence adduced in their favor appears to be similar in kind to that for Tertiary land bridges, and not any more convincing. If in the one case it must be otherwise interpreted, then it should be so in the other.

The conformation of the bottom of the Atlantic is very little suggestive of any former bridges, except in the extreme north (from Newfoundland to Ireland, or across Greenland, Iceland and Scandinavia). A long, depressed, irregular trough or series of "deeps" on each side fronts the continental borders which are areas of elevation and erosion. These deeps may have been formed by the withdrawal of material that has gone to build up the lighter fragmented rocks of the continental platform borders,

aided by the loading of heavier calcareous and ferruginous deep-sea deposits. Since the principal elevation and erosion of the continental border strips fronting the Atlantic took place during the Palæozoic, it is suggested that the present conformation of the Atlantic bottom dates back in part at least to that era.

THE IONIZATION AND ACTIVITY OF LARGELY IONIZED SUBSTANCES

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In applications of the ionic theory of solutions it is customary to employ, in accordance with the original hypothesis of Arrhenius, as a measure of the degree of ionization of salts, acids, and bases, the ratio of the equivalent conductance of the substance at any given concentration to the limiting value of the equivalent conductance as the concentration approaches zero, where the ionization may be assumed to be complete.

This assumption, however, is not a necessary conclusion from the fundamental theory of ionic conduction. According to this theory, the equivalent conductance Λ (which is by definition the quantity of electricity which under a potential-difference of one volt passes per second between electrodes of indefinite extent 1 cm. apart, between which is placed that quantity of solution which contains one equivalent weight of the ionizing substance) is for a uniunivalent substance given by the expression $\Lambda = \gamma F(U^+ + U^-)$, in which γ is the fraction of the substance ionized (equal in this case to the number of equivalents of each ion present in the solution), F the quantity of electricity (96,500 coulombs) associated with each equivalent of ion, and U^+ and U^- the mobilities of the positive and negative ions (that is, their velocities through the solution under a potential-gradient of one volt per centimeter). For the equivalent conductance Λ_0 at zero concentration, where the ionization becomes complete, we have the corresponding expression $\Lambda_0 = F(U_0^+ + U_0^-)$. Combining these two equations we get

$$\frac{\Lambda}{\Lambda_0} = \gamma \frac{U^+ + U^-}{U_0^+ + U_0^-}.$$

From this equation it is evident that Λ/Λ_0 is equal to the ionization only when the mobilities of the ions can be assumed constant up to the concentration under consideration. That they should remain constant so long as the solution does not differ appreciably from water as a viscous medium, may seem reasonable; but, in view of possible electrical effects resulting from the large electric charges on the ions, it is by no means certain.

This simple assumption has been justified in the case of slightly ionized acids and bases, where the ion-concentration in the solution is small, by the fact that the so-determined ionization values change with the concentration just as the mass-action law requires. This, however, is not true even approximately in the case of salts and of the largely ionized acids and bases (such as hydrochloric acid and sodium hydroxide); and we are forced to conclude, either that owing to the change in the ion-mobilities the conductance-ratio is not a correct measure of ionization, or that the chemical activity or mass-action effect of ions, and perhaps also of the un-ionized molecules present with them, is not proportional to their concentration, as the ordinary mass-action law assumes.

In either case the conductance-ratio affords us no reliable information as to the chemical activity of ions; and we must turn to other properties for a quantitative measure of this important factor, which determines the equilibrium of all chemical reactions between salts, acids, and bases in solution, and also the magnitude of many physical properties thermodynamically related to the activities.

The term activity must, in the first place, be defined in a precise way; and from a chemical standpoint the most practical method is to define it, as was proposed by G. N. Lewis,[1] as the quantity which when substituted for the concentration of the substance in mass-action expressions will express its effect in determining the equilibrium. Thus the activity of the substance is its "effective concentration" from this mass-action view-point.

Correspondingly, the most obvious method of determining the relative activities of a substance in solutions of different concentrations is to find its concentrations in a gaseous phase in equilibrium with the solutions; for in gases at low pressure the concentration and activity can ordinarily be assumed to be proportional. For example, we know that the ratio of the activities of un-ionized hydrochloric acid in its 11-molal and 8-molal aqueous solution at 30° is 12.0, since the partial vapor-pressures of the hydrochloric acid in those solutions have been found to be 11.3 and 0.94 mm. of mercury. This quantity is also the ratio of the products of the activities of the hydrogen-ion and chloride-ion in the two solutions, since these products are by definition the quantities that must be substituted in the mass-action expression for the equilibrium of the reaction $HCl = H^+ + Cl^-$. Thus denoting the pressures in the two solutions by p_1 and p_2, the activities of the un-ionized molecules by a_1 and a_2, and those of the ions by a_1^+, a_1^-, and a_2^+, a_2^-, we get:

$$\frac{p_1}{p_2} = \frac{a_1}{a_2} = \frac{a_1^+ a_1^-}{a_2^+ a_2^-}.$$

This direct method is, however, of very limited applicability in the case of largely ionized substances, since they seldom have appreciable vapor-

pressures. We have recourse, therefore, to a simple thermodynamic relation between activity and electromotive force. This relation may be derived by considering the work or free-energy decrease attending the transfer of one mol of the substance (for example, of 1 HCl) from the solution in which its vapor-pressure is p_1 to that in which it is p_2. This free-energy decrease $-\Delta F$ is given by the familiar expression $-\Delta F = RT \log (p_1/p_2)$. In this expression, in view of the above considerations, we may substitute for the vapor-pressure ratio the ratio $(a_1^+a_1^-)/(a_2^+a_2^-)$ of the product of the activities of the ions, yielding the equation

$$-\Delta F = RT \log \frac{a_1^+ a_1^-}{a_2^+ a_2^-}.$$

We thus obtain what may be regarded as a secondary, but more general definition or measure of activity.

The simplest process from a theoretical standpoint (aside from that already described involving passage through the vapor phase) by which a substance can be transferred from one solution to another is one in which this transfer is brought about in a voltaic cell. Thus in the case of hydrochloric acid, we can cause a transfer of one mol of the acid from concentration c_1 (activity a_1) to concentration c_2 (activity a_2) by causing one faraday (F coulombs) to pass through the cell

$$H_2 \text{ (1 atm.)}, HCl(c_2), AgCl + Ag, HCl(c_1), H_2 \text{ (1 atm.)}.$$

The electromotive force E of this cell multiplied by the quantity of electricity F is, therefore, the work which can be obtained from the change in state under consideration, or the free-energy change attending it. That is,

$$-\Delta F = EF = RT \log \frac{a_1^+ a_1^-}{a_2^+ a_1^-} = RT \log \frac{c_1^2 \alpha_1^+ \alpha_1^-}{c_2^2 \alpha_2^+ \alpha_2^-}.$$

It will be noted that in the last of these expressions there has been written, in place of the activities a of the ions, products $c\alpha$, in which the quantity α, called the activity-coefficient, is evidently the factor by which the total concentration c of the substance must be multiplied to give the activity of the ion.

By the use of this electromotive-force method the authors of this paper have, with the aid of their students, carried out a series of determinations of the activities of typical substances. Two of these researches, those on potassium chloride[2] and on hydrochloric acid,[3] have already been published; and two more, on lithium chloride and potassium hydroxide, will soon be described in detail in the *Journal of the American Chemical Society*. These last investigations were carried out, with the aid of grants from the Carnegie Institution of Washington, by Mr. J. A. Beattie and Mr. Ming Chow, respectively, using cells, with dropping amalgam electrodes, of the following types:

Ag + AgCl, LiCl (c_2), Li in Hg, LiCl (c_1), AgCl + Ag.

Hg + HgO, KOH (c_2), K in Hg, KOH (c_1), HgO + Hg.

It is the purpose of this paper to summarize and compare the results of these investigations, and to state the general conclusions to which they lead.

From the observed values of the electromotive forces of these cells there were calculated by the equation given above the products $\alpha^+ \alpha^-$ of the activity-coefficients of the two ions at various concentrations, the value of the products at the lowest concentration (0.001 or 0.0035 molal) at which accurate measurements could be made being assumed equal to the conductance-ratio Λ/Λ_0 at that concentration. These activity-coefficient products were plotted against the logarithm of the concentrations, and those corresponding to round concentrations were read off.

The following table contains the values of the square root of the so-obtained products, that is, the values of the expression $(\alpha^+\alpha^-)^{1/2}$, which represents the geometrical mean of the activity-coefficients of the positive and negative ions of the substance. This table also contains the corresponding values of the conductance-ratio Λ/Λ_0, multiplied by the ratio η/η_0 of the viscosity of the solution to that of pure water, this last serving to correct approximately for the frictional resistance of the medium to the passage of the ions through it.

TABLE 1

ACTIVITY-COEFFICIENTS AND CONDUCTANCE-VISCOSITY RATIOS

Mols. per 1000 g. water	ACTIVITY-COEFFICIENTS				CONDUCTANCE-VISCOSITY RATIOS			
	KCl	LiCl	HCl	KOH	KCl	LiCl	HCl	KOH
0.001	0.979	0.976			0.979	0.976	0.990	
0.003	0.943	0.945	0.990	0.982	0.968	0.962	0.986	0.980
0.005	0.923	0.930	0.965	0.975	0.956	0.949	0.981	0.975
0.010	0.890	0.905	0.932	0.961	0.941	0.932	0.972	0.963
0.030	0.823	0.848	0.880	0.920	0.914	0.904	0.957	0.939
0.050	0.790	0.817	0.855	0.891	0.889	0.878	0.944	0.925
0.100	0.745	0.779	0.823	0.846	0.860	0.846	0.925	0.910
0.200	0.700	0.750	0.796	0.793	0.827	0.812	0.909	0.891
0.300	0.673	0.738	0.783	0.769	0.807	0.792	0.903	0.889
0.500	0.638	0.731	0.773	0.765	0.779	0.766	0.890	0.884
0.700	0.618	0.734	0.789	0.772	0.761	0.751	0.874	0.879
1.000	0.593	0.752	0.829	0.786	0.742	0.737	0.845	0.877
2.000			1.040					
3.000		1.164	1.402					

The table contains the results of only the above-described researches carried out under our direction. It should be mentioned, however, that exact electromotive-force measurements from which activities can be derived have also been made by Jahn[4] on potassium, sodium, and hy-

drogen chlorides, by Harned[5] on potassium chloride, and by Linhart[6] on hydrochloric acid. As the results of Harned supplement at higher concentrations those for potassium chloride here presented, it may be stated that, assuming a constant transference-number of 0.497 for the potassium ion and an activity-coefficient of 0.745 at 0.1 molal as given in the table, his data lead to the following values:

Normal concentration.....	0.2	0.3	0.5	0.7	1.0	2.0	3.0
Activity-coefficient.....	0.688	0.[illegible]7	0.624	0.608	0.593	0.572	0.586

The results presented in the table may be summarized as follows:

1. In the case of all four substances the activity-coefficient decreases with increasing concentration much more rapidly than does the conductance-viscosity ratio, the differences amounting to from 7 to 15% at 0.1 molal, and from 5 to 18% at 0.5 molal.

2. In the case of all the substances except potassium chloride the activity-coefficient, unlike the conductance-viscosity ratio, passes through a pronounced minimum in the neighborhood of 0.5 molal, afterwards increasing rapidly at the higher concentrations. Even potassium chloride, according to Harned's data, has a minimum activity-coefficient in the neighborhood of 2-normal.

3. The activity-coefficient even at moderate concentrations varies considerably with the nature of the substance; thus its value at 0.5 molal is 64% for potassium chloride, 73% for lithium chloride, and 77% for hydrochloric acid and for potassium hydroxide.

From these facts we may draw the general conclusions that the conductance ratio can no longer be regarded as even an approximate measure of the activity of the ions of largely ionized substances in their mass-action and thermodynamic relations; that this activity varies with the concentration, differently in the case of different substances; and that for the present it can be determined only empirically for each substance, with the aid of measurements of chemical equilibria, electromotive force or freezing-point.[7]

It is, moreover, evident that the activity-coefficient of the ion-constituents cannot be proportional to and mainly determined by the fraction of the substance ionized, for this fraction could not increase with increasing concentration unless the ionizing power of the medium becomes much greater at moderate concentrations; and even then, it could not become greater than unity, as is actually the case with the activity-coefficient of hydrochloric acid above 2-molal.

The results here presented do not show whether or not the conductance-ratio is equal to the degree of ionization. But these two quantities can hardly be equal in view of the fact that the conductances of the two ion-constituents of most uniunivalent substances seem to vary by different percentage amounts with increasing concentration, as may be seen from

Noyes and Falk's[8] summary of the experimentally determined transference-numbers. These numbers, which are equal to the ratio $v^+/(v^+ + v^-)$ of the mobility of the cation-constituent to the sum of the mobilities of the two ion-constituents, show variations that correspond to changes in the ratio v^+/v^- of the mobilities of the two ion-constituents between zero concentration and 0.3 normal, of $4^1/_2\%$ in the case of sodium chloride, $7^1/_2\%$ in the case of hydrochloric acid, and 24% in the case of lithium chloride. Moreover, MacInnes[9] has shown that the chloride-ion constituent has the same equivalent conductance in 0.1 normal solutions of lithium chloride, potassium chloride, and hydrochloric acid, although the conductance-ratios Λ/Λ_0 for these substances are 0.833, 0.862 and 0.925; so that, if we account for the constancy of the chloride-ion conductance by the probable assumptions that the three substances are equally ionized and that the chloride-ion has the same mobility in the three solutions, we must conclude that the hydrogen-ion and lithium-ion decrease in mobilities between zero concentration and 0.1 normal by amounts that differ from each other by 10%—a result that makes it not unreasonable to suppose that the whole decrease in equivalent conductance (of $7^1/_2\%$ and 16% in the two cases) may be due entirely to decrease in mobility of the ions, and not at all to decrease in ionization.

When, indeed, in addition to these conclusions that neither the activity-coefficients nor the conductance-ratio is determined primarily by the degree of ionization, we take into consideration the fact that there is no property which affords any direct evidence of the existence of un-ionized molecules in solutions of most of the largely ionized inorganic substances up to moderate concentrations, it seems advisable to adopt for the present the hypothesis that such substances are completely ionized, and to attribute the decrease in the conductance-ratio wholly to decrease of ion-mobility, and the change in activity-coefficient entirely to some unknown effect of a physical nature.

It would lead far beyond the scope of this paper to discuss the many classes of phenomena that seem to substantiate this assumption. A summarized description of them was given many years ago by one of the authors of this paper,[10] who at that time, however, suggested that they might be explained more fully by the hypothesis that the ions are partially united as a result solely of their electrical attraction into loosely bound molecules, which differ fundamentally from the stable molecules formed as a result of chemical affinity in accordance with the law of mass-action. The known facts may, however, prove to be better accounted for by the simple hypothesis of complete ionization, supplemented by some other, purely physical, explanation of the cause of the decrease of ion-mobility and of ion-activity with increasing concentration; and this now seems the most promising method of treatment, as has recently been urged by various authors.[11] As said above, we cannot here discuss in detail the hypothesis

of complete ionization; but in closing it may be pointed out that it accounts for the remarkable facts that so many very dissimilar chemical substances (for example, hydrochloric acid and potassium chloride) seem to be equally ionized, and that a volatile substance like hydrochloric acid does not have an appreciable vapor-pressure even in 1-normal solution where 15% of it must be assumed to be in the un-ionized state, if the conductance-ratio is taken as a measure of ionization. It may also be mentioned that it avoids the improbable conclusions as to the abnormal activity of the un-ionized molecules to which solubility-effects, interpreted under the older assumptions, lead.[12]

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THE COMMUTATIVITY OF ONE-PARAMETER TRANSFORMATIONS IN REAL VARIABLES

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If $X = \Sigma\xi_i(x_1 \ldots x_n)\frac{\partial}{\partial x_i}$ and $Y = \Sigma\eta_i(x_1 \ldots x_n)\frac{\partial}{\partial x_i}$ be the differential symbols of two one-parameter transformations, the known condition for the commutativity of the finite transformations is the identical vanishing of the commutator $(XY) = XY - YX$. The proof given by Lie-Engel, applying to the case of analytic functions, depends on expansions in powers of the canonical parameters. The computation of (XY) according to the original definition involves the use of the second partial derivatives of the coefficients ξ, η, but the final form, containing only first derivatives, is

$$(XY) = \sum_i (X\eta_i - Y\xi_i)\frac{\partial}{\partial x_i}. \quad (1)$$

The proof here sketched, in which the commutator is to be considered defined directly by (1), shows that for the case of real variables it is sufficient to assume the existence of continuous, first partial derivatives only of the ξ's and η's. The basis of the proof is formed by familiar theorems on the existence and uniqueness of the solutions of differential equations and their differentiability with respect to parameters. A minimum range of variation for which the results can be known to apply could be specified by the use of inequalities such as naturally occur in connection with those theorems.

With the canonical parameters denoted by α and β, and the corresponding finite transformations by X_α and Y_β, let the point $(x_{10}, \ldots, x_{n0})$ be transformed first by Y_β then by X_α, defining thus the functions $x_i(\alpha, \beta)$. These are then determined by the differential equations

$$D_\alpha x_i(\alpha,\beta) = \xi_i[x(\alpha,\beta)], \quad (2)$$

in which the values initial for $\alpha = 0$ are determined by

$$D_\beta x_i(0,\beta) = \eta_i[x(0,\beta)], \quad (3)$$

where x_i (0, 0) is to be x_{i0}. The functions x_i (α, β) then exist for a certain range of variation of α and β; and with respect to the latter they have derivatives satisfying the equations

$$D_\alpha D_\beta x_i(\alpha,\beta) = \sum_j \xi_{ij}[x(\alpha,\beta)]D_\beta x_j(\alpha,\beta), \quad (4)$$

in which ξ_{ij} means $\partial\xi_i/\partial x_j$. Now $D_\alpha\eta_i[x(\alpha,\beta)]$ exists and is given by

$$D_\alpha\eta_i[x(\alpha,\beta)] = \sum_j \eta_{ij}[x(\alpha,\beta)]\xi_j[x(\alpha,\beta)], \quad (5)$$

which by virtue of the assumed identical vanishing of (XY) is equivalent to

$$D_\alpha\eta_i[x(\alpha,\beta)] = \sum_j \xi_{ij}[x(\alpha,\beta)]\eta_j[x(\alpha,\beta)]. \quad (6)$$

Comparison of (4) and (6) shows that the $D_\beta x_i(\alpha,\beta)$ and the $\eta_i[x(\alpha,\beta)]$ satisfy the same system of linear differential equations, and according to (3) they agree for $\alpha = 0$. Hence, for every α,β,

$$D_\beta x_i(\alpha,\beta) = \eta_i[x(\alpha,\beta)]. \quad (7)$$

Thus the functions $x_i(\alpha,\beta)$ are the same as would be obtained by the opposite sequence, X_α followed by Y_β, showing the condition in question to be sufficient.

A sense in which the vanishing of (XY) is also necessary appears likewise in connection with the differential equations. If for both orders of

transformation the $x_i(\alpha,\beta)$ be the same, then corresponding to those orders is to be inferred the existence of the derivatives

$$D_\alpha D_\beta x_i = \sum_j \xi_{ij} D_\beta x_j = \sum_j \eta_j \xi_{ij} = Y\xi_i,$$

$$D_\beta D_\alpha x_i = \sum_j \eta_{ij} D_\alpha x_j = \sum_j \xi_j \eta_{ij} = X\eta_i.$$

If these are to agree the commutator must vanish at all points actually occurring in the transformation; a similar limitation in the meaning of "identical" may be understood in the proof of sufficiency.

THE INTENSITIES OF X-RAYS OF THE L SERIES
II. THE CRITICAL POTENTIALS OF THE PLATINUM LINES

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Communicated by Edwin B. Wilson. Read before Academy, November 10, 1919

Introduction.—This work is a continuation of that of Webster and Clark, reported in these PROCEEDINGS[1] in 1917. Part of the present work was done at Harvard University with the apparatus described in the earlier paper, and part with my new apparatus at the Massachusetts Institute of Technology. The object in view is the investigation of the laws relating intensity to potential, for the L-series lines, for the purpose of comparison with current theories of X-ray spectra, and the present paper deals with the determination of the critical potentials of the platinum lines of medium intensity, the stronger ones having been reported in the previous paper and the fainter ones, observed only in tungsten by Dershem[2] and Overn,[3] being so faint as to require a much more prolonged study.

Apparatus.—The work at Harvard showed that with the slit widths needed for accurate intensity measurements it would be difficult to work with certainty on any lines but the strong ones, when the voltage was near the critical value. As the previous work of the author on the rhodium K series[4] had shown that photography gave good results in such work it was decided to use it here. In this case, where the lines are many and scattered and faint, the best instrument seemed to be the bent mica spectrograph of de Broglie and Lindemann[5] with which they have obtained excellent spectrograms. These show spectra of six orders, called first to sixth inclusive, though I think the last one, from its angle, must really be the seventh rather than the sixth, which must be very faint. The grating space is about 10 Ångstroms and the third and fifth orders are the strongest.

In the present work, to increase the intensity even at a sacrifice of resolving power, I used a long radius, either 40 or 80 cm., with the tube 75 cm. from the mica and the plate as shown in figure 1. In practice, even with the best mica, there are faults in its structure that make it necessary to take several photographs at each voltage with different positions of the mica so as to insure clear reflection for each line in one case or another. To avoid scattered rays the mica was held on the edges of two

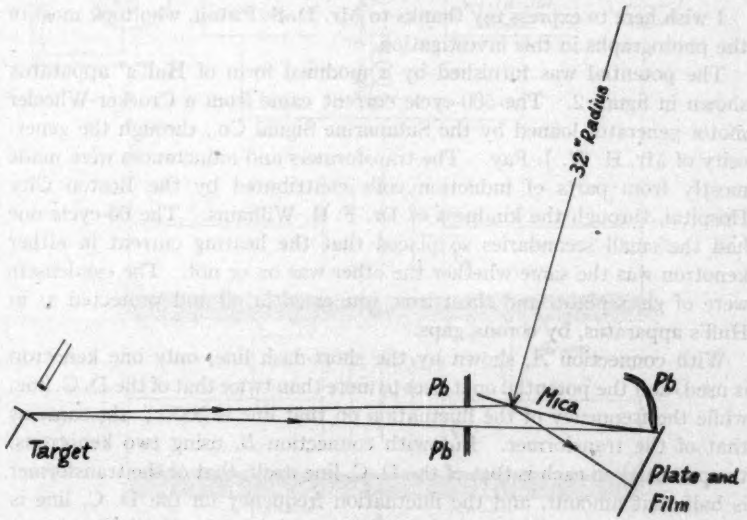

FIG. 1

brass plates, far enough apart so that no direct rays struck them, and the direct beam through the mica was caught in a sheet of lead. The lines were identified from a chart made from the wave-length measurements of Siegbahn and Friman,[6] and the voltmeter (Chaffee type, as in the previous work) was calibrated by the wave-length $\lambda_{min.}$ of the high frequency end of the third order spectrum as determined from this chart. In all exposures near any critical voltages the voltage was regulated to a mean deviation of $^1/_5$ to $^1/_2$ of 1% from the average value.

An important improvement in the voltmeter, introduced in the work at Harvard, was the use of a single insulator only, directly under the suspended system, with fairly good electrostatic screening. This prevents disturbances from indeterminate charges on the insulator which may otherwise make serious errors.

Each spectrogram was taken on one or two Eastman Dupli-tized X-ray films backed by a Seed Graflex plate. For locating very faint lines this combination was useful because with the plate and film, or two films, in contact after development any relative motion of the two would make

the spectrum flash out stronger when the images coincided. This method worked especially well when they were still wet. The parts where the general radiation was not too strong were also examined by holding the film against a white paper in a strong light, and a negative lens was also used. Since these methods were needed it is obviously impossible to show the faint lines in a reproduction even when there was no doubt of their existence in the original. Therefore, no reproduction is attempted here.

I wish here to express my thanks to Mr. D. S. Piston, who took most of the photographs in this investigation.

The potential was furnished by a modified form of Hull's[7] apparatus shown in figure 2. The 500-cycle current came from a Crocker-Wheeler motor generator loaned by the Submarine Signal Co., through the generosity of Mr. H. W. J. Fay. The transformers and inductances were made mostly from parts of induction coils contributed by the Boston City Hospital, through the kindness of Dr. F. H. Williams. The 60-cycle one had the small secondaries so placed that the heating current in either kenotron was the same whether the other was on or not. The condensers were of glass plates and sheet iron, immersed in oil and protected as in Hull's apparatus, by corona gaps.

With connection A, shown by the short-dash line, only one kenotron is used, and the potential on it rises to more than twice that of the D. C. line, while the frequency of the fluctuation on that line is 500⁓, the same as that of the transformer. But with connection B, using two kenotrons, the potential on each is that of the D. C. line itself, that of the transformer is half that amount, and the fluctuation frequency on the D. C. line is doubled. It should be noticed that to produce this double frequency it is most essential that no part of the transformer secondary or first or second condensers should be grounded.

The constants of the apparatus were approximately as follows: $C_1 = 3 \times 10^{-3}$ mfd, $C_2 = C_3 = 1.5 \times 10^{-3}$ mfd, L_1 (sum of the two sides plus twice the mutual inductance) = 20,000 henries, L_2 = 15,000 henries. Such large inductances are not strictly necessary, and were used only because they were at hand. They were measured by using 90 kv. (measured by spark) at 500⁓ with an A. C. voltmeter (current type) in series in the middle of the line. As the voltage fluctuation is approximately $\frac{I}{C_1C_2C_3L_1L_2\omega^5}$, it is extremely small, probably not over a few volts under the worst conditions. The resistance of L_1 and L_2 together, measured by D. C., was about 0.3 megohm. When running, a current type voltmeter in series with C_2 and C_3 showed no measurable current, though of course it showed easily the current in C_1.

Incidentally, it may be noted that the above expression for the fluctuation should contain also the factor $(1 - C_2M\omega^2)$, where M is the mutual inductance between L_1 and L_2. This factor could readily be used to neu-

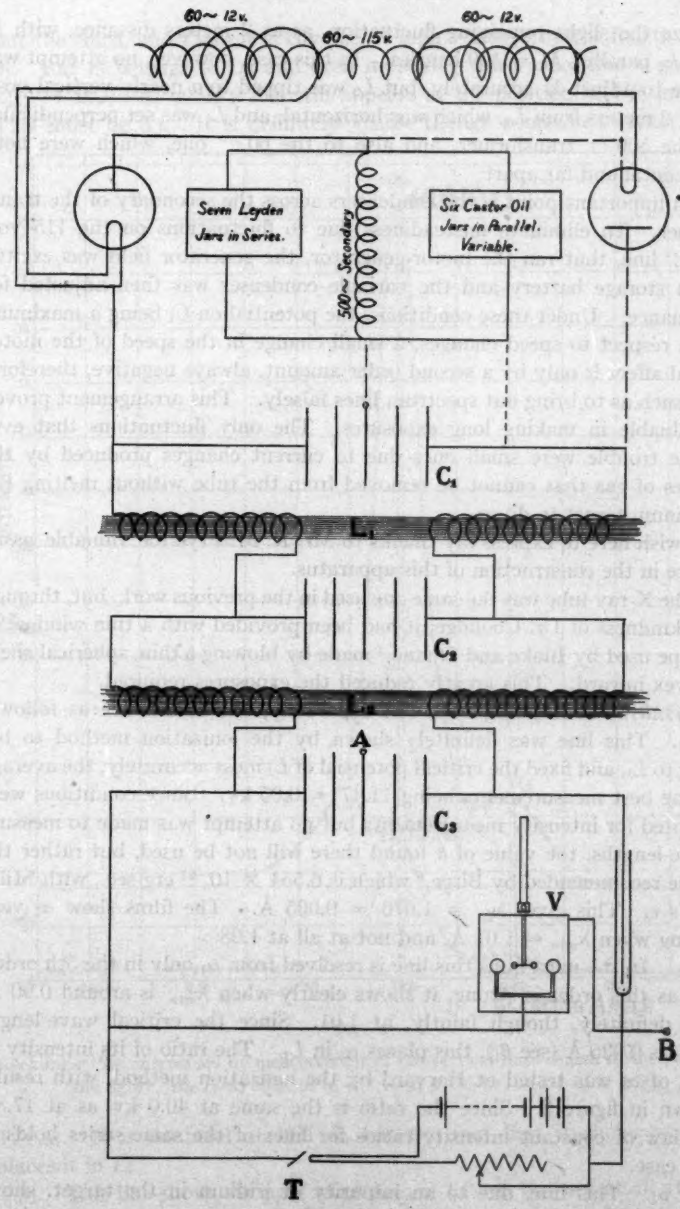

FIG. 2

Note: Short-dash line, connection *A* only. Long-dash lines, connection *B* only. Ground only at point *A* at high potentials and only at point *B* at low.

tralize the slight remaining fluctuation, as at 2 meters distance, with L_1 and L_2 parallel, $M = 100$ henries. In this case, however, no attempt was made to adjust M accurately, but L_2 was tipped to a nearly vertical position, 2 meters from L_1, which was horizontal, and L_1 was set perpendicular to the 500 ~ transformer, and also to the 60 ~ one, which were both horizontal and far apart.

An important point is the condensers across the secondary of the transformer. To eliminate unsteadiness due to fluctuations on the 115-volt D. C. line, that ran the motor-generator, the generator field was excited by a storage battery and the variable condenser was then adjusted for resonance. Under these conditions, the potential on C_1 being a maximum with respect to speed changes, a small change in the speed of the motor could affect it only by a second order amount, always negative, therefore, not such as to bring out spectrum lines falsely. This arrangement proved invaluable in making long exposures. The only fluctuations that ever made trouble were small ones due to current changes produced by the traces of gas that cannot be removed from the tube without melting the platinum target to do so.

I wish here to express my thanks to Mr. R. M. Frye for valuable assistance in the construction of this apparatus.

The X-ray tube was the same one used in the previous work, but, through the kindness of Dr. Coolidge, it had been provided with a thin window of a type used by Blake and Duane,[8] made by blowing a thin, spherical shell, convex inward. This greatly reduced the exposures required.

Results.—Considering each line separately, the results are as follows:

α_1. This line was definitely shown by the ionization method to belong to L_1, and fixed the critical potential of L_1 most accurately, the average of the best measurements being 11.47 ± 0.05 kv. Since conditions were adapted for intensity measurements but no attempt was made to measure wave-lengths, the value of h found there will not be used, but rather the value recommended by Birge,[9] which is 6.554×10^{-27} erg sec., with Millikan's e. This gives $\lambda_{L_1} = 1.076 \pm 0.005$ Å. The films show α_1 very strong when $\lambda_{min} = 1.01$ Å, and not at all at 1.08.

α_2. In the mica films this line is resolved from α_1 only in the 5th order, but as this order is strong, it shows clearly when λ_{min} is around 0.90 Å, and definitely, though faintly, at 1.01. Since the critical wave-length of L_2 is 0.935 Å (see β_1), this places α_2 in L_1. The ratio of its intensity to that of α_1 was tested at Harvard by the ionization method, with results shown in figure 3. Since the ratio is the same at 40.0 kv. as at 17.85, the law of constant intensity ratios for lines of the same series holds in this case.

Ir α_1. This line, due to an impurity of iridium in the target, shows faintly but definitely when $\lambda_{min} = 1.01$ Å, but not at 1.08.

l. This line is too faint to show near its critical potential in any order

but the third, and there it is covered at high voltages by the fourth order β_1. But β_1 belongs to L_2, and even its strong third order line is gone at $\lambda_{min} = 0.945$ Å, while a line still appears at the position of 4 β_1 and 3 l. This must be 3 l. It is definitely visible though somewhat fainter than

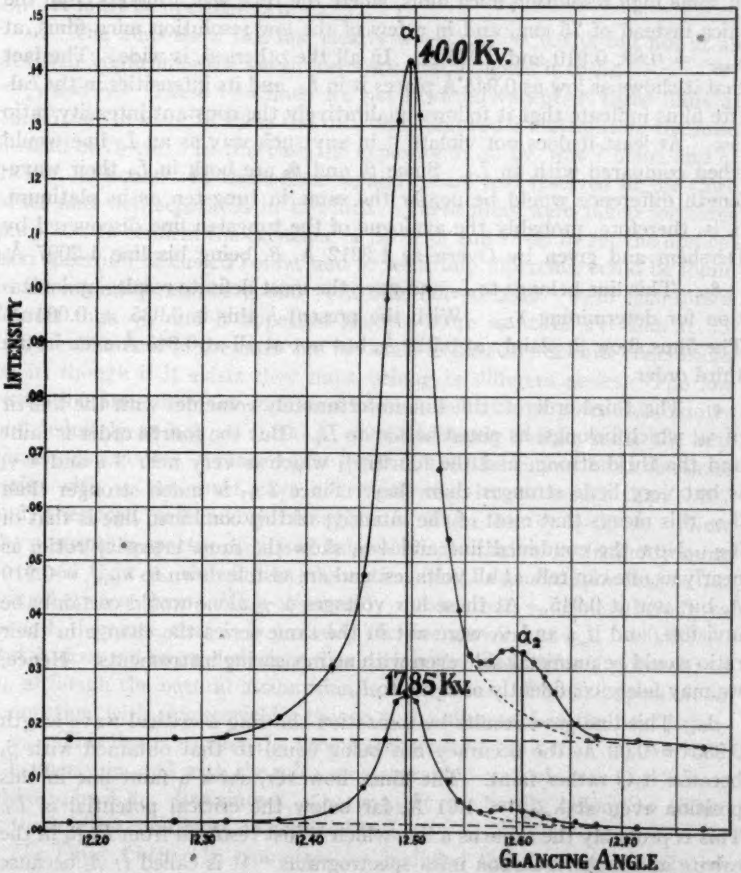

FIG. 3

Reckoning the intensities by measurement of the vertical lines drawn to the peaks in the figure, the ratio of α_1 to α_2 is 1.11 at 17.85 kv. and 1.10 at 4.00.

3 *Ir* α_1. It is doubtful at 1.01 Å, but the fact that it shows at 0.945 places it in L_1.

β_2. This line shows strongly when $\lambda_{min} = 1.01$ Å, but not at all at 1.08, as one might expect from the ionization work previously reported, which placed it in L_1.

β_5. This line shows well at high voltages, and faintly but distinctly when $\lambda_{min} = 1.01$ Å. This places it in L_1.

β_6. In the calcite spectrograms taken at Harvard there is a faint companion of β_5 at a wave-length greater by 0.010 ± 0.002 Å. This also shows in some high resolution mica films, where the tube was 3 meters from the mica instead of 75 cm., and in a few of the low resolution mica films, at $\lambda_{min} = 0.88$, 0.910 and 0.945 Å. In all the others β_5 is wide. The fact that it shows as low as 0.945 Å places it in L_1, and its intensities in the calcite films indicate that it follows qualitatively the constant intensity ratio law. At least it does not violate it in any such way as an L_2 line would when compared with an L_1. Since β_5 and β_6 are both in L_1 their wave-length difference would be nearly the same in tungsten as in platinum. β_6 is, therefore, probably the analogue of the tungsten line discovered by Dershem and given by Overn as 1.2212 Å, β_5 being his line 1.2097 Å.

β_1. This line belongs to L_2 and gave the most definite results by ionization for determining λ_{L_2}. With the present h this is 0.935 ± 0.004 Å. The films show β_1 plainly at 0.910 Å, but not at all at 0.945 Å even in the third order.

η. The third order of this line unfortunately coincides with the fourth of γ_2, which belongs, as noted below, to L_2. But the fourth order is faint and the third strong, and the fourth γ_1 which is very near $3\,\eta$ and $4\,\gamma_2$ is but very little stronger than they. Since $3\,\gamma_1$ is much stronger than $3\,\gamma_2$ this means that most of the intensity of this combined line is that of $3\,\eta$. Now the combined line and $4\,\gamma_1$ show the same intensity ratio, as nearly as one can tell, at all voltages, and are visible down to $\lambda_{min} = 0.910$ Å, but not at 0.945. At these low voltages $4\,\gamma_2$ alone would certainly be invisible, and if η and γ_1 were not in the same series the change in their ratio would be unmistakable even with no measuring instruments. Hence, we may fairly confidently assign η to L_2.

β_4. This line gave results by ionization showing a critical wave-length 0.935 ± 0.02 Å, the accuracy not being equal to that obtained with β_1 because it is rather faint. The films, however, show a faint line in this position even at $\lambda_{min} = 1.01$ Å, far below the critical potential of L_2. This is probably the same as a line which is just resolved from *Pt* β_4 in the calcite and high resolution mica spectrograms. It is called *Ir* β_2 because its wave-length is that of the iridium line and it obviously does not belong to L_2. But as all lines are rather wider in the mica photographs and the work of Dershem and Overn showed a line in tungsten that might be near this point in platinum, further work with a high resolving power and long exposures is needed. As the present spectrograph is unsuitable for this and several other problems presented by the very faint lines, a more suitable one is now being constructed by Mr. F. C. Hoyt.

Ir β_1 *and Ir* β_2. These lines appear in the calcite and high resolution

mica films, and behave like *Pt* β_1 and *Pt* β_2, the changes in relative intensities with voltage being very striking in both cases.

β_3. This line is obscured by β_2 except in the calcite films. Its behavior there is similar to that of the L_2 lines and quite different from that of the L_1. It must be in either L_2 or L_3.

λ_1. The films show this line clearly when $\lambda_{min} = 0.910$, but not at all at 0.945, confirming the ionization work that assigned it to L_2.

γ_2 *and* γ_3. These two lines are not resolved except in three films at 35, 25 and 18 kv. In these the tube was removed 3 meters from the mica instead of 75 cm. In this case the exposure at 35 kv. was 7 hours and at 18 kv., 30 hours. In these films γ_2 and γ_3 are just resolved in the third order and well separated in the fifth. These films were taken for three purposes, to confirm the existence of β_6, *Ir* β_1 and *Ir* β_2, to get the absorption spectrum discussed below, and to see if any difference could be found in the intensity ratio of γ_2 and γ_3 at different voltages. γ_3 in each film is fainter than γ_2, and it appeared slightly more so at 18 kv. than at 35, but the difference in the ratio was too small to base any definite conclusions on it, though if it exists they must belong to different series. The low resolution films show the combined line $\gamma_{2,3}$ well at high potentials, faintly but definitely at $\lambda_{min} = 0.895$ Å, and it is barely visible under the best conditions at 0.907. Since $\lambda_{\gamma_4} = 0.900$ Å, this line cannot be in the same series with γ_4 but must have a critical wave-length longer than 0.907 and, therefore, presumably belong to L_2 where $\lambda_{L_2} = 0.935$ Å. Now the absorption spectra discussed below indicate that γ_3 is distinctly more absorbed than γ_2, showing an absorption limit, A_2, corresponding to L_2, lying between them. This apparently means that γ_3 cannot belong to L_2 and, therefore, that γ_2 is probably the line showing at $\lambda_{min} = 0.907$ Å. But it does *not* mean definitely that γ_3 has the same critical potential as γ_4, although the natural assumption is that it has. This is important in connection with Sommerfeld's theory to be discussed in the next paper.

γ_4. This line is so near the bromine absorption limit that any work on it is uncertain, and with the mica spectrograph 3 γ_4 is obscured by 2 *Ir* α_1 and 5 γ_4 by 4 β_4. But since $\lambda_{\gamma_4} < \lambda_{L_2}$ or λ_{L_1} it can hardly belong to either of these series, and must be ascribed to L_3.

The Faint Lines.—In this class are included the lines found only by Dershem and Overn, in tungsten. For these, further work will be necessary, with high resolving power and very long exposures.

The Critical Points.—The question arises whether the critical wave-lengths determined by potentials are identical with the absorption limits, as they seem to be in the K series. The critical wave-lengths found by Clark and me for L_1 and L_2 were identical, within limits of error, with the wave-lengths of β_5 and γ_2, respectively, provided $h = 6.554 \times 10^{-27}$ erg sec., and, therefore the results of various measurements of absorption limits are compared with these lines in the following table:

TABLE 1

ELEMENT	λ_{A_1}	λ_{β_5}	$\lambda_{\beta_5}-\lambda_{A_1}$	λ_{A_2}	λ_{γ_2}	$\lambda_{\gamma_2}-\lambda_{A_2}$	λ_{A_3}	λ_{γ_4}	$\lambda_{\gamma_4}-\lambda_{A_3}$
Tungsten	1.230[10]	1.2097[3]	—0.020	1.081[10]	1.0596[3]	—0.021	1.025[10]	1.0263[3]	+0.001
Tungsten	1.215[11]	1.2097[3]	—0.005						
Platinum	1.070[11]	1.072[6]	+0.002						
Platinum	1.072[12]	1.072[6]	0.000	0.934[12]	0.033[6]	—0.001			
Gold	1.041[11]	1.035[6]	—0.006	0.901[11]	0.898[6]	—0.003	0.861[11]	0.869[6]	+0.008
Gold	1.042[12]	1.035[6]	—0.007	0.914[12]	0.898[6]	—0.016			
Mercury	1.009[11]	1.013[13]	+0.004						
Thallium	0.977[11]	0.977[6]	0.000	0.843[11]	0.844[6]	+0.001			
Lead	0.948[11]	0.953[13]	+0.005	0.814[11]	0.820[6]	+0.006			
Lead	0.949[14]	0.953[13]	+0.004	0.813[14]	0.820[6]	+0.007	0.781[14]	0.792[6]	+0.011
Bismuth	0.924[11]	0.923[6]	—0.001	0.789[11]	0.794[6]	+0.005	0.756[11]	0.762[6]	+0.006
Thorium	0.760[11]	0.767[13]	+0.007	0.627[11]	0.637[13]	+0.010	0.607[11]	0.610[13]	+0.003
Uranium	0.721[11]	0.726[13]	+0.005	0.591[11]	0.598[13]	+0.007	0.567[11]	0.571[13]	+0.004
Mean			—0.001			0.000			+0.006

From this table it would appear that A_1, A_2 and A_3 are probably at nearly the same wave-lengths as β_5, γ_2 and γ_4, respectively, in every element. But most of these results were obtained with different apparatus for the two kinds of measurement, and there is considerable disagreement. As even a slight difference in wave-length one way or the other is of great theoretical interest, it seemed desirable to check this point by using a screen of H_2PtCl_6 on blank films. This was attempted in two of the high resolving power spectrograms. The results were not very satisfactory, owing to the strong absorption by the other substances than platinum in the screen, and the presence of the less absorbed radiation of higher frequencies, in the fifth order, at the most interesting part of the third. But they seem to indicate that A_1 is within a very few thousandths of an Ångstrom of β_5, and that A_2 is between γ_2 and γ_3, γ_3 being apparently the more strongly absorbed of these lines. This is consistent with the conclusion reached above, that γ_2 belongs to L_2 and γ_3 to L_3, but the evidence is unsatisfactory and none was obtained on A_3. This apparatus was not designed for high resolving power but it is hoped that this point will be settled with the other apparatus now being constructed by Mr. F. C. Hoyt for work on the fainter lines.

Summary of Results.—We have assigned the lines to the various series as follows:

To L_1, l, α_2, α_1, β_2, β_6 and β_5;

To L_2, η, β_4, β_1, γ_1, γ_2 and perhaps β_3;

To L_3, γ_4, probably γ_3 and perhaps β_3.

Unassigned, all of Dershem's and Overn's faint lines except β_6, which is probably one of them.

Critical points:

$\lambda_{L_1} = 1.076 \pm 0.005$ Å, approximately $= \lambda_{\beta_6}$;

$\lambda_{L_2} = 0.935 \pm 0.004$ Å, approximately $= \lambda_{\gamma_2}$;

λ_{L_1}, λ_{L_2} and λ_{L_3} are probably exactly equal to λ_{A_1}, λ_{A_2} and λ_{A_3} though more work is needed on this point.

Intensity ratios: constant for any pair of lines of the same series, with changes in voltage, as far as they have been investigated.

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THE EFFECT OF PHYSICAL AGENTS ON THE RESISTANCE OF MICE TO CANCER

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Read before the Academy, November 10, 1919

The report which I wish to present today has to do with further progress in the work which I reported before the Academy in June, 1915. I will review that work briefly in order to orient you with the observations made since then.

The fundamental point in immunity to transplanted cancer is that there are two types of resistance, the so-called natural and induced immunity. Mice may be rendered resistant by an injection of a quantity of homologous living tissue given at least a week or ten days before the cancer inoculation; this is called induced immunity. A variable proportion of mice inoculated with a transplantable tumor will be resistant; this is called natural immunity. The histological manifestation of resistance about an introduced cancer graft in these two types of immunity is the same and

is characterized by a lymphoid infiltration of the tissues around, and later, an actual invasion of the graft.

We first showed that there was an actual increase in the circulating lymphocytes, accompanied by hyperplasia of the lymphoid elements following cancer inoculation into immune animals. If this crisis was prevented by the destruction of the lymphocytes the immunity of the animal was destroyed. Furthermore, animals with tested immunity could be rendered susceptible by a similar destruction of the lymphocytes. The method we used for the destruction of the lymphocytes was that of small repeated doses of X-rays. It was established that this procedure would practically deplete the animal of lymphoid tissue without apparent injury to other important structures and without detectable influence on the animal's general health.

In the course of this investigation of the action of X-rays it was noted that while repeated small or a single large dose would destroy the lymphoid tissue, a single, small exposure to a ray of suitable quality would stimulate the lymphocytes. The stimulation was judged by the numbers of circulating lymphocytes and the state of activity of the germinal centers in the spleen and lymph nodes as indicated by the number of mitotic figures present. This method of increasing the lymphoid elements of the body was first used in an attempt to increase the resistance of mice to replants of their own spontaneous tumors. By this treatment we increased the resistance from 3.4% in our control series to 50% in the treated series. By a similar induced lymphocytosis we have been able to develop a resistance to transplanted cancers which compares most favorably with the immunity following tissue injection. The procedure here was to expose a number of mice to a stimulating dose of X-rays and then inoculate them with a transplantable cancer a week later, at the same time inoculating a series of controls. The following table gives the result of these experiments:

EXPERIMENT NUMBER	I	II	III	AVERAGE
Takes in X-rayed mice	25.0%	29.0%	28.6%	27.5%
Takes in control mice	77.8%	87.5%	60.0%	75.1%

We next turned our attention to finding other methods of producing lymphoid stimulation. Several agents have been found other than X-rays, but only one so far which gives a reaction extensive enough and of sufficient duration for experimental purposes. Dry heat ranging from 55 to 65° C. applied to the whole animal for five minutes was found to produce a stimulation of the lymphocytes and of lymphoid tissue of marked intensity, the increase in the number of lymphocytes persisting for a number of days. Mice treated in this manner and then inoculated with cancer a week later showed a striking degree of immunity as compared with the control animals inoculated with the same tumor at the same time. The following table gives the result of these experiments:

EXPERIMENT NUMBER	I	II	III	AVERAGE
Takes in heated mice.....	30.0%	30.0%	50.0%	36.6%
Takes in control mice.....	77.8%	78.8%	94.5%	83.6%
Number of mice used.....	20	33	54	Total 107

The effect of heat stimulation was also tested on the resistance of mice with spontaneous tumors to replants of their own cancers. The result in this case was even better than that obtained with the small doses of X-rays. The heated mice had an immunity of 59.4% as compared with 50% in the X-rayed series and 3.4% in the untreated animals.

It will be noted that in our experiments with the transplanted tumors we made our transplantations one week after exposure to the heat or the X-rays. This time was selected at first because the greatest stimulation occurred then. Further experiments indicated that if animals treated by either of these methods were inoculated during the first two or three days after treatment there was either no immunity or very slight evidence of it. The following table illustrates this point:

	AVERAGE
Takes in mice X-rayed 1 week before inoculation.....	27.7%
Takes in mice X-rayed 1 to 3 days before inoculation.....	60.0%
Takes in control mice.....	67.0%
Takes in mice heated 1 week before inoculation.....	36.6%
Takes in mice heated 1 to 3 days before inoculation.....	77.7%
Takes in control mice.....	86.2%

This observation offers a very interesting parallel with that on immunity induced by tissue injection. The immunity is non-operative during the first few days and is at its best between seven and ten days after the injection. It seems to me of considerable interest that we are able to induce the same degree of immunity by the use of physical agents as by the use of what we may call a biological agent. The points in common are: the lymphocytosis induced by the physical agents, which occurs normally after the use of the biological agent, and the latent period before the immunity, become evident after the use of all three of the agents.

Summary.—It was first shown that animals immune to transplantable cancer showed a large increase in the circulating lymphocytes after cancer inoculation. This reaction is accompanied by hyperactivity of the lymphoid tissue of the spleen and lymph nodes. If the reaction is prevented by the destruction of the lymphoid tissue the immunity is destroyed, and the animal becomes susceptible to cancer inoculation.

Two methods have been found whereby the lymphocytes may be markedly increased along with a heightened activity of the germinal lymphoid centers: (1) by exposure to diffuse, small doses of X-rays; and (2) by exposure to dry heat. The lymphocytosis and lymphoid hyperplasia induced by these two physical agents are associated with an immunity to transplanted cancer equally as great as that arising from tissue injections.

Furthermore, these methods are capable of increasing the resistance of mice to replants of their own spontaneous tumors. From the evidence at hand it seems then that the immunity aroused by these two physical agents has at least one other point of similarity to that induced by tissue injection, namely, a period of latency after the exposure before the immunity becomes evident. Whether the tissue injection, the small dose of X-rays, or the dry heat induce changes in the organism other than those associated with increase in the lymphoid tissue which would account for the immunity, is impossible to state at the present time; but the evidence now at hand points at least to the lymphoid tissue as an important agent in the immunity reaction to transplanted cancer of mice.

The work reported in this paper was carried out with the assistance of Herbert D. Taylor, John J. Morton, W. D. Witherbee, Waro Nakahara, and Ernest Sturm.

THE PROTEIN REQUIREMENT OF MAINTENANCE IN MAN

By H. C. Sherman

Department of Chemistry, Columbia University

Communicated by W. A. Noyes, November 17, 1919

During the past four years a number of experiments have been carried out to test the nutritive requirements of maintenance in healthy men and women, and the efficiency of diets derived chiefly from the cereal grains in meeting these requirements. In connection with this work the results of all available data from previous investigations which seemed to lend themselves to direct quantitative comparison, have been brought together.

Probably the best present indication of the amount of protein or nitrogen actually required for the maintenance of the average adult is to be obtained by averaging the observed output of nitrogen in all available experiments, upon normal men and women, in which the energy value of the food was appropriate to the size and activity of the subject and the intake of nitrogen appears to have been just about sufficient to result in equilibrium of intake and output. Since a considerable and rather variable amount of time is required for the body to adjust its rate of nitrogen output to the rate of intake, it is probable that the "indicated protein requirement" obtained by averaging all available experiments will be somewhat greater than the minimum amount of protein on which the same subjects could actually have established and maintained equilibrium had the experiments been sufficiently prolonged. In other words, for the practical purpose of indicating how much protein the food must furnish in order to provide for adult maintenance such an average will err on the side of safety in that it may be expected to be appreciably above the minimum which would actually suffice to keep normal individuals in equilibrium. Two other in-

fluences tending toward an over-estimate of the protein requirement should also be noted since one or both of them appear to have played a significant part in the great majority of experiments which have been made in the past. These are: First, the tendency in experiments of this sort to reduce the intake of food as a whole, thus creating a deficit in the energy supply, which must interfere with the economical use of protein; second, hesitation, because of past over-estimates of the protein requirement, to reduce the amount of protein in the food to a sufficiently low figure to really test the minimum on which equilibrium could be established and maintained.

Every effort has here been made to decide in an objective manner which of the past experiments should be included in the average; yet an element of judgment necessarily enters into the selection, especially as some experiments have been more carefully planned and more rigorously controlled than others.

According to the rigorousness of the selection, the results may be given as follows: First, 109 experiments show a range of 21 to 65 grams and an average of 44.4 grams of protein per 70 kg. of body weight per day; second, 94 of these experiments show a range of 29 to 56 grams with an average of 42.8 grams; third, 76 of the same experiments show a range of 30 to 50 grams with an average of 40.6 grams. For convenience of comparison, all the results whether the subjects be men or women were here reduced to a uniform basis of 70 kg. of body weight—the usual basis for the statement of food requirements "per man per day."

These data reveal no evidence of a sex difference in protein requirement, since 67 experiments upon men indicated a requirement of 0.633 gram and 42 experiments upon women indicated a requirement of 0.637 gram of protein per kilogram of body weight per day.

In our own more recent experiments, including both men and women, although the protein of the food was almost entirely that of the cereal grains, the amounts required for maintenance have usually been less than the averages above given. Thus, a man of 80 kg. established and maintained equilibrium on a daily intake of 37.5 grams of protein, of which 96% was furnished by ordinary wheat bread. A woman of 55 kg. found 27 grams of maize protein (from corn meal) almost sufficient, while 30 grams per day of protein, of which 88% was from corn meal, 10% from milk, and 2% from apple, proved more than sufficient. The same subject showed essentially the same requirement when oatmeal was substituted for corn meal as the chief source of protein, and a second woman subject also found fully adequate a diet which furnished not over 0.6 gram of protein per kilogram of body weight, about nine-tenths of the protein being derived from oatmeal and one-tenth from milk.

Thus it appears that in the maintenance of healthy men and women an intake of not over 35 to 45 grams of protein "per man" of 70 kg. per day is sufficient, even when the protein is not selected as of especially high

nutritive efficiency, and that a "standard" allowance of 1 gram protein per kilogram of body weight per day provides a margin of safety of from 50 to 100% above the minimum amount actually required to maintain equilibrium.

For growth and reproduction the amounts of protein required are relatively larger than for maintenance, and the selection of the protein is also of greater importance.

The data of all of the experiments here considered are summarized, with fuller discussion and with citation of original sources, in a paper which is being offered for publication in the *Journal of Biological Chemistry*.

THE TRANSPLANTING OF SEA ANEMONES BY HERMIT CRABS

By R. P. Cowles

Department of Zoölogy, Johns Hopkins University

Communicated by H. S. Jennings, November 6, 1919

It is well known that hermit crabs inhabit the vacant shells of molluscs, that as they grow they change from smaller shells to shells of larger size and that hydroids, sea anemones and other animals are frequently attached to these shells. Several observers have reported that they have seen hermit crabs remove sea anemones from their old habitations and transplant them on their new shells. Such observations are mentioned in a few zoölogical text-books but usually the treatment is such as to leave the impression that there is an element of doubt as to the occurrence of the habit. For this reason I shall describe the behavior of individuals belonging to two species of hermit crabs, *Pagurus deformis* and *Pagurus asper*, occurring in the sea about the Philippine Islands, which bear sea anemones on their shells (Dolidae, Strombidae, Cassis, etc.) and which transfer these animals when they change their shells. My observations are worthy of note since they were made in the presence of four co-workers (Dr. L. E. Griffin, Mr. Alvin Seale, Professor A. L. Day and Professor S. F. Light), and since the individuals of the species of hermits mentioned both usually carry two kinds of sea anemones, one, a species whose individuals are large, the other, a species whose individuals are small, the former being fixed, as a rule, on the top of the shell and the latter generally on the under side near the protruding head of the hermit crab.

The following account of the behavior of the hermit crabs and sea anemones with reference to one another is undoubtedly in harmony with what occurs in nature although it deals with observations made in the laboratory: A hermit inhabiting a shell bearing two large sea anemones on the upper surface and a small one in the mouth of the shell was placed

in an aquarium containing a clean, empty Dolium shell of a larger size than the one in use. The hermit began to examine the new shell almost immediately, put its pinchers and some of its legs inside of the shell and remained in this position for a considerable length of time. Occasionally the pinchers were moved about and were used apparently to examine the outside of the shell. Then, suddenly, the abdomen was inserted into the new shell and the hermit without moving away grasped one of the large anemones clawing, pinching and pulling it. The anemone instead of contracting as it would if disturbed by the observer remained expanded even though the mauling it received was really very strenuous and although it was frequently jammed up against the newly occupied shell. After these movements had continued at least for ten minutes the base of the anemone began to loosen in several places. Instead of completing its work at once the hermit began to pinch and claw the other large anemone which withdrew its tentacles, soon however protruding them again. Then suddenly the hermit left the second anemone, picked off the small, white one and applied it at the mouth of the new shell almost directly under its own head, where it soon became firmly attached. The crab now attacked again one of the large anemones, removed it easily, turned it round and round between its legs and pinchers and finally pushed the base against the side of the new shell. It failed to become attached, slipped down on the hermit's legs, stuck to them for a moment, dropped off and finally attached itself on the glass bottom of the aquarium. Again the hermit crab seemed to lose interest in the anemone on which it was working and began tugging, pinching and scratching the only remaining anemone attached to its old shell. After a long period of handling and some little prying up of the edges of the base of the anemone, during which time the tentacles contracted completely, the anemone suddenly slipped off apparently of its own accord. (Strange as it may appear the crab seems never to cause any injury although the base of the anemone is very thin and when taken off by man is easily torn.) The hermit now caught the anemone which had just slipped off, rolled it around and around for a few seconds and then with the aid of the hind legs applied the tentacle-side against the shell. Again the anemone slipped off and was disregarded for a moment while the hermit picked up the other anemone. Still holding the latter it lifted up the one that had just slipped off and rolled them both around for some little time. Finally one became attached to the side of the shell by one edge of the base and was left to shift for itself. The other was passed up to the opposite side of the shell with the aid of the posterior legs of the hermit and soon both anemones became firmly attached with their tentacles beautifully expanded. While the actions of this hermit crab were not nearly so accurate as those of some others I have observed, yet like all of them it showed a constant and hurried activity which seemed to indicate that some inherited nervous condition

existed which was directing its actions. Furthermore, during the time in which this remarkable behavior was taking place the hermit crab, although at other times reacting quickly to movements outside of the aquarium, showed almost no reaction to the stimuli which are ordinarily produced by people passing or moving in front of the aquarium. This account describes a single series of observations but several other series were made in which the behavior was similar.

It seems probable that the anemones become associated with the hermit crabs very early in life, and that possibly they become attached in larval life to mollusc shells inhabited by hermits.

While the anemones are undoubtedly benefited by their association with the hermit crabs since the latter lead a wandering life in heavy growths of eel grass which harbor many small organisms, and while they may often take morsels from decaying animals upon which the hermits feed, the writer has never seen the hermits transfer pieces of food to the sea anemones as has been described by one investigator.

In the absence of any experimental work on these animals it cannot be proved that the sea anemone affords any protection for the hermit but it seems probable that stinging cells of the former would prevent the hermits being eaten by fishes.

We cannot believe that the hermit crab during its life time has learned by experience that it derives any advantage from transplanting the sea anemone although we know that crabs in general do profit by experience, and yet assuming that the remarkable behavior of the hermit is due to instinct, that is, to an "inherited combination of reflexes" which have been so brought together by the nervous system that the behavior has become fixed and adaptive in the species, it is extremely difficult to conceive how it has come about.

SPECTRA OF EXPLOSIONS

By J. A. Anderson

Mount Wilson Observatory, Carnegie Institution of Washington

Communicated by G. E. Hale, December 2, 1919

Some experiments with explosions of fine, iron wires by electrical means have led to the development of a method of producing a brilliant continuous spectrum extending throughout the visible spectrum and as far into the ultra-violet as can be recorded by a quartz spectrograph. On the continuous background appear as absorption lines practically all the iron lines usually found in the arc. For example, in the green region between $\lambda 5150$ and $\lambda 5700$, which is unfavorable for reversals in general, this spectrum on a scale of $6A$ per millimeter shows 128 absorption lines due to iron; Burns' table for the same region contains 215 lines, and

Rowland gives 180 lines of intensity 1 or higher, as due to iron. Both of these are from spectrograms having a scale of 1A per millimeter.

The apparatus employed consists of a small 25,000 volt transformer with a mechanical rectifier to charge a glass plate condenser of 0.4 microfarad capacity. The condenser is discharged through a circuit consisting of a spark gap 2 cm. long, in series with which is a fine iron wire 5 cm. long and weighing about 2 mg. When the condenser discharges the wire explodes with a loud report and a brilliant flash of light, and if it is enclosed in a tube of wood having an internal diameter of 1 cm. or less, the continuous spectrum is observed on viewing the tube, end on. The average duration of the explosion is of the order of 10^{-5} seconds, and ten explosions are sufficient to record a fully exposed spectrum of the λ4000 region, using a grating spectrograph giving a dispersion of 6A per millimeter. An exposure to the sun in this region requires $^1/_{40}$ second, from which it follows that this new source of light is of the order of 100 times as bright as the sun. With a quartz spectrograph the ultra-violet region at λ2300 (scale 4A per millimeter) is well recorded with 10 explosions, and the region at λ3500 (scale 20A per millimeter) with 1 or 2 explosions.

A few trial exposures have been made using nickel, copper, and manganin wires. These indicate that with nickel, the spectrum is considerably brighter than with iron, while with copper it is much weaker. Manganin and iron give about the same intensity.

With a larger condenser and higher voltage it is hoped that the brightness may be materially increased.

REPORT OF THE AUTUMN MEETING

PREPARED BY THE HOME SECRETARY

The Autumn Meeting of the Academy was held at Yale University, New Haven, Ct., on November 10 and 11, 1919.

Fifty-six members were in attendance, as follows: Messrs. C. G. Abbot, Bailey, Benedict, Boltwood, Bumstead, Cannon, Cattell, Chittenden, Cross, Cushing, Dana, Davenport, Davis, Day, Donaldson, Elkin, Flexner, Gomberg, Gooch, E. H. Hall, Harrison, Hastings, Henderson, Howard, Jennings, Johnson, Kasner, Leuschner, Lusk, Lyman, Mayor, Meltzer, Mendel, C. E. Mendenhall, Millikan, E. S. Morse, E. F. Nichols, A. A. Noyes, H. F. Osborn, T. B. Osborne, Parker, Pearl, Prudden, Russell, Schuchert, Setchell, Squier, Stratton, A. Trowbridge, Verrill, Walcott, Webster, H. S. White, Edmund B. Wilson, Edwin B. Wilson, R. W. Wood.

BUSINESS SESSIONS

The President announced the deaths of W. G. Farlow, elected to membership in the Academy in 1879; Joseph Barrell, elected in 1919; Lord Ray-

leigh, elected foreign associate in 1898; and Emil Fischer, elected foreign associate in 1904.

The Home Secretary stated that a Section of Engineering had been established and that it is now constituted as follows: Messrs. H. L. Abbot, J. J. Carty, W. F. Durand, J. R. Freeman, H. M. Howe, F. B. Jewett, G. O. Squier, D. W. Taylor. All members of the Sections of Physics and Chemistry were given an opportunity to remain with the section with which they had been affiliated or to be placed in the Section of Engineering.

Messrs. L. O. Howard, C. E. Mendenhall, and David White were appointed to audit the accounts of the Treasurer.

Messrs. J. C. Merriam, Gano Dunn, L. J. Henderson, A. L. Day, and W. J. V. Osterhout were elected members, and Mr. Raymond Pearl was re-elected chairman, of the Editorial Board of the PROCEEDINGS, to serve for three years. Mr. E. B. Wilson was re-elected Managing Editor for one year.

The following cable, prepared by the Foreign Secretary at the request of the President and forwarded to *Nature*, was read:

"The President of the National Academy of Sciences requests me to offer his congratulations to *Nature* on the occasion of its jubilee. During a period of specialization *Nature's* extensive survey of the progress of research has stimulated wider vision and larger effort. In spite of repeated discouragement it has urged upon the statesmen of two generations the vital importance of science to the nation. At a time when the branches of science, no longer isolated, are uniting in common channels and when governments, once unappreciative, are recognizing the bearing of research on national security and public welfare, we rejoice in *Nature's* expanding influence and the higher opportunities opening to it in a newly ordered world."

The President reported that Mrs. Mary Clark Thompson had completed the establishment of a fund amounting to $10,000, the income of which is to be applied to a gold medal of appropriate design, to be awarded annually by the Academy for the most important services to geology and palaeontology. The medal is to be known as the MARY CLARK THOMPSON GOLD MEDAL. Mrs. Thompson previously gave an additional $1,000 for the preliminary expenses of dies, etc. The following recommendation, in acknowledgment of this gift, was adopted:

"That the National Academy of Sciences express to Mrs. Mary Clark Thompson the appreciation of its members, especially those working in the fields of geology and palaeontology, for this munificent gift to promote the recognition of research in these subjects."

In accordance with the recommendations of the Henry Draper Committee, the following grants and award of medals were approved:

1. $400 to Dr. S. A. MITCHELL, Director of the Leander McCormick Observatory, University of Virginia, to complete the purchase of a measuring microscope for use in the photographic determination of stellar paral-

laxes, on the basis of observations made with the 27-inch refracting telescope. The Academy awarded the sum of $250 from the Draper Fund to Dr. Mitchell in 1916 to apply on the purchase of this instrument. The microscope cost $650. The proposed grant of $400 will complete the purchase, in effect making the instrument the property of the Academy, and Professor Mitchell will devote an equivalent sum, $400, to the other needs of his parallax research.

2. $300 to Dr. JOEL STEBBINS, Professor of Astronomy in the University of Illinois, to assist in the further development and application of the photo-electric cell photometer.

3. $400 to Dr. FRANK SCHLESINGER, Director of the Allegheny Observatory, to enable him to test an automatic zenith camera for the determination of terrestrial latitudes with the expectation that the results will be more accurate than any hitherto obtained by other means. It is proposed that this instrument be mounted at least temporarily at the International Latitude Observatory, Ukiah, California, where the astronomer in charge, Mr. Neubauer, will operate it for a year or two as a labor of love. The grant is needed to install the instrument at Ukiah and to make certain auxiliary apparatus required in its operation.

The award of the HENRY DRAPER GOLD MEDAL to ALFRED FOWLER, F.R.S., Professor of Astrophysics, Imperial College, South Kensington, London, at the time of the stated meeting in April 1920, for his researches in celestial and laboratory spectroscopy, which have led to a valuable increase of our knowledge of sunspots, comets, and the stars—especially red stars of Secchi's Type III.

At the dinner held at the Hotel Taft on November 11, the DANIEL GIRAUD ELLIOT MEDAL AND HONORARIUM was presented to Mr. C. WILLIAM BEEBE, of the American Museum of Natural History, New York, for his work, *Monograph of the Pheasants*. Dr. Osborn, Chairman of the Committee on the Award of the Elliot Medal, outlined briefly the history of this award, and Mr. Beebe responded, giving a short, interesting talk about his researches on pheasants. Immediately following the dinner, President Walcott presented the following recommendations from the Council, which were unanimously adopted:

"That the medal for eminence in the application of science to the public welfare be awarded at the Annual Meeting in April 1920, to HERBERT C. HOOVER for his applications of science in the conservation, selection and distribution of food."

"That the Home Secretary be requested to transmit the thanks of the Academy to Yale University, President Hadley, the Board of Governors of the Graduates' Club, and to the members of the Academy forming the local committee, for the courtesies extended to the members of the National Academy of Sciences during the Autumn Meeting of 1919."

SCIENTIFIC SESSIONS

The following papers were presented at the scientific sessions, November 10 and 11. One asterisk denotes presentation by invitation; two asterisks, presentation only by title; a dagger denotes that the article has been offered for publication in the PROCEEDINGS.

W. M. DAVIS: Four cliff islands in the coral seas.

EDWARD KASNER: Some new theorems in the dynamics of a particle.

*HENRY LAURENS and HENRY D. HOOKER: The relative physiological efficiency of spectral lights of equal radiant energy content.

*RICHARD S. LULL: A study in synthetic paleontology.

**Biographical memoir of Samuel Wendell Williston.

*YANDELL HENDERSON: The adjustment to the barometer of the haemato-respiratory functions in man.†

*GEORGE A. BAITSELL: Development of connective tissue in the amphibian embryo.†

C. G. ABBOT: A new method for determining the solar constant of radiation.†

*LEIGH PAGE: A kinematic interpretation of electromagnetism.†

C. B. DAVENPORT and ALBERT G. LOVE: Defects found in drafted men.

*JAMES B. MURPHY: The effect of physical agents on the resistance of mice to cancer.†

JOHN M. CLARKE: Some restorations of extinct vertebrates.

The great sponge colonies of the Devonian: their origin, rise, and disappearance.

*HENRY G. BARBOUR and J. B. HERRMANN: On the mechanism of fever reduction by drugs.†

EDWIN H. HALL: The Thompson effect from the point of view of dual electric conductivity.

*ALOIS F. KOVARIK: A statistical method for studying the radiations from radioactive substances and the X-rays.

*M. C. WINTERNITZ: Anatomical changes in the respiratory tract associated with acid insufflation.

*FRANCIS G. BLAKE: Experimental pneumonia in monkeys.

R. A. MILLIKAN: The effect upon an atom of the passage of an alpha ray through it.

The extension of an ultra-violet ray spectrum.

*HIDEYO NOGUCHI: Leptospira icteroides and yellow fever.

*H. H. LAUGHLIN: Calculating ancestral influences in man.

*FRANK P. UNDERHILL, JAMES A. HONEIJ and L. JEAN BOGERT: Calcium and magnesium metabolism in certain diseases.†

HENRY FAIRFIELD OSBORN and CHARLES CRAIG MOOK: Reconstruction of the skeleton of the sauropod dinosaur Camarasaurus Cope (Morosaurus Marsh).†

WILLIAM K. GREGORY (communicated by H. F. Osborn): Restoration of camarasaurus and life model.†

WILLIAM DILLER MATTHEW (communicated by H. F. Osborn): Plato's Atlantis in paleography.†

SIMON FLEXNER: Lethargic encephalitis and poliomyelitis.†

A. G. MAYOR: The history of the coral reefs of Tutuila, Samoa.

**Biographical notice of Samuel Hubbard Scudder.

*R. A. DALY: Changes of land and ocean levels.

*SAMUEL RANDALL DETWILER: On hyperplasia of nerve centers resulting from excessive peripheral loading.†

T. B. OSBORNE: Concentration of the water-soluble vitamine or yeast.

*G. P. CLINTON: The manner of infection of white pine by the blister rust.

T. B. OSBORNE and LAFAYETTE B. MENDEL: Certain chemical properties of foods and their relation to nutrition.

**F. LOHNIS (introduced by Raymond Pearl): Studies upon the life cycles of bacteria.

**E. W. NELSON (introduced by C. D. Walcott): Lower California and its natural resources.

**F. W. CLARKE: A recalculation of the atomic weights.

**EDWIN R. A. SELIGMAN: Biographical memoir of Richmond Mayo-Smith.

**THOMAS C. CHAMBERLAIN: Biographical memoir of Charles R. Van Hise.

RAYMOND PEARL: On the embryological basis of human mortality.†

*E. W. BROWN: Jupiter's five attendant planets.

*C. C. LITTLE: Notes on human sex ratio.

*A. M. BANTA: Sex intergrades and their peculiar inheritance.

*J. K. WHITTEMORE: The starting of a ship under constant power.

*LORANDE LOSS WOODRUFF: Endomixis in relation to selection in paramecia.

A. A. NOYES and DUNCAN MACINNES: The activity of ions in largely ionized substances.†

F. G. BENEDICT: The basal metabolism of boys from one to thirteen years of age.†

**EDWARD S. MORSE: Biographical memoir of Charles S. Minot.

EDWIN B. WILSON: Radiationless orbits.†

*DAVID L. WEBSTER: The intensities of X-rays of the L series, II. The critical potentials of the platinum lines.†